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# **Report of The Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario**

Volume Two

**J. Stefan Dupré**  
Chairman

**J. Fraser Mustard**  
Commissioner

**Robert J. Uffen**  
Commissioner

Donald N. Dewees  
Director of Research

John I. Laskin  
Legal Counsel

Linda B. Kahn  
Executive Co-ordinator





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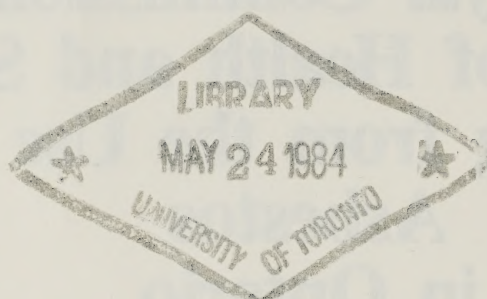
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## **Part III**

# **Asbestos in Fixed Workplaces**



## **Chapter 6 Fixed Place Industry: Asbestos Use and Control**

### **A. Introduction**

Having explored the health effects of asbestos fibre exposure, we now turn to an examination of the uses of asbestos in Ontario, the exposure of workers to asbestos fibres, and the measures that must be taken adequately to protect the health and safety of Ontario workers. Workplace exposure can be divided into two broad categories, currently recognized by the Ontario Ministry of Labour: fixed place exposure and non-fixed place exposure.<sup>1</sup> Fixed workplaces include manufacturing operations, mining, shipbuilding and repair, railroad equipment maintenance, and automotive brake maintenance. Non-fixed workplaces include building construction, renovation or demolition projects. The exposure of workers in non-fixed workplaces, and in buildings, will be discussed in Part IV of this Report. The present Part deals with fixed workplaces.

We begin this chapter by presenting information on the level of activity in asbestos manufacturing in Ontario and in Canada, along with asbestos product trade statistics which indicate the economic activity that occasioned past and current worker exposures. We also summarize the exposure of Ontario workers to airborne asbestos since the mid-1950s. We then review the technology for controlling worker exposure to asbestos and present estimates of the cost implications for some of the major manufacturing activities that currently exist in Ontario. Because replacing asbestos with other fibres may be an important method of controlling worker exposure to asbestos, the cost and availability of asbestos substitutes are discussed. The health effects of the substitutes are then reviewed to determine whether we can have confidence that substitution will reduce, rather

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<sup>1</sup>*Occupational Health and Safety Act*, R.S.O. 1980, c. 321, s.1, par. 23.

than increase, the risk to which Ontario workers are exposed. The final sections of this chapter deal with fixed workplace asbestos exposures other than in manufacturing. While mining of asbestos has never been a major activity in Ontario, we present a brief profile of asbestos and related mining in the province with estimates of the worker exposures that have resulted. We also review exposures in such domains as automotive brake repair, ship-building, and railroad equipment construction and maintenance.

In Chapter 7 we go on to examine the problems of measuring asbestos fibre exposures in fixed workplaces, and ways to improve current measurement methods. The health risks to Ontario workers from fixed workplace exposures are then estimated, relying on the health effects information developed in Chapter 5. The current regulations for worker exposure in fixed workplaces in Ontario and elsewhere are reviewed and the control limits that should govern worker exposure to asbestos in Ontario are considered and recommended. Work practices necessary to protect workers in fixed workplaces where monitoring is not feasible are also discussed.

Chapter 8 moves beyond numerical control limits to the implementation of controls in fixed workplaces. The operations of the *Occupational Health and Safety Act* and its subordinate Regulation Respecting Asbestos are explored, weaknesses identified, and recommendations for improvements made. This chapter expresses our conviction that control limits only create an illusion of healthy workplaces in the absence of implementation measures bent on actually achieving those control limits, and moving beyond them where practicable.

## **B. Profile of the Canadian Asbestos Industry**

### **B.1 Asbestos Manufacturing in Ontario**

Determining which firms in Ontario belong to the asbestos manufacturing industry is difficult because the industry must be defined on the basis of an input that it purchases rather than on the basis of the type of output it produces. The firms classified as belonging to the asbestos industry will use asbestos in a wide variety of products in widely varying amounts, and may, save for the use of asbestos, be completely unrelated.

A written submission made by the Ontario Ministry of Labour to this Commission identified 15 firms as the asbestos manufacturing industry in Ontario.<sup>2</sup> However, two of those firms had discontinued the use of

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<sup>2</sup>Ontario, Ministry of Labour, Written submission to the Royal Commission on Asbestos, #43, February 1981, p. 7.

asbestos and one had abandoned manufacturing and begun to engage in asbestos insulation removal. Thus, this list includes at best 12 major manufacturers of asbestos products. To supplement this list, the Ministry of Labour surveyed its Industrial Health and Safety Branch files of 191 companies whose workers were under surveillance by the Occupational Health Branch for use of asbestos. Of these 191 companies, 90 reported recent asbestos exposure.<sup>3</sup> From the list of 90 asbestos users, we eliminated firms that consumed asbestos in only marginal quantities, or were involved in the installation or modification of a product containing asbestos and not its actual manufacture. Combining the remaining firms with the firms identified in the Ministry of Labour submission yielded the list of 23 firms in Table 6.1. The diversity of the industry is readily apparent from examining the products manufactured and the number of exposed employees. These firms do not constitute a single homogenous industry. Products manufactured range from asbestos-cement pipe and construction products to brake linings. Save for the use of asbestos as an input, the firms in the industry are completely unrelated. There is no industry association to which most of the members of this group belong. Neither is there any general contact among most members of the group.

Table 6.1 indicates whether the manufacturing firm is owned by another company and the country of origin for the parent company. Of the 23 firms listed in the table, slightly more than half are controlled by companies outside of Canada, all but two of which are located in the United States. In cases of foreign control, the parent firm almost always controls 100% of the subsidiary company. Typically, the foreign firm has not one but several Canadian subsidiaries, sometimes producing in different provinces, sometimes dividing responsibility for production, sales, distribution, and other functions. The other firms in the Canadian family usually do not produce asbestos-containing goods. However, it is not uncommon for firms in the family outside of Canada to be involved in some type of asbestos-related activity.

In addition to the number of Canadian firms owned by the parent, Table 6.1 provides information on the assets of the Canadian asbestos manufacturing firms where this information is available. The asset information is not representative because it can only be obtained for the largest firms. There are no readily available public records of the assets of the smaller domestic firms. Aggregate data, however, show that for 1981, the asbestos manufacturing firms listed in Table 6.1 had assets totalling

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<sup>3</sup>Ibid. See also Appendix 6 to the Ministry of Labour's written submission to the Royal Commission on Asbestos, "Companies Using Asbestos and Under Medical Surveillance by the Occupational Health Branch, Updated September 22, 1980," Appendices, pp. 31-37; and revised list issued by letter from Mr. Arthur L. Gladstone, Senior Policy Advisor, Occupational Health and Safety Division, Ontario Ministry of Labour to the Royal Commission on Asbestos, 6 June 1983.

Table 6.1  
Ontario Asbestos Product Manufacturers  
(1981 Data Except as Noted)

Company	Product	Assets (\$ Millions)	Workers Under Surveillance, 1980*	Parent Company		
				Name	Country	Number of Firms in Family**
Abex Industries Ltd.	Friction materials	50.4	134	I.C. Industries Inc.	U.S.A.	15
Able Gasket and Materials Ltd.	Gaskets		15		Canada	
Acro Gasket Industries Ltd.	Gaskets		23			
BBA Automotive Ind. (Cdn.) Ltd.	Brake parts	7.9	83	BBA Group Ltd.	U.K.	2
Bakelite Thermosets Ltd.	Thermosets		20	Lockston Ind. Ltd.	Canada	2
Bendix Auto of Canada Ltd.***	Friction products	65.4	480	The Bendix Corporation	U.S.A.	13
Canadian Cylinder Company Ltd.	Absorbant in acetylene cylinders		19	Pacific Lumber Corp.	U.S.A.	6
Cataract Canvas Ltd.			NA†		Canada	
Certified Auto. Prod. Ltd.	Friction products		316	Lear Siegler Inc.	U.S.A.	6
A.W. Chesterton Co.	Valve packing asbestos yarn		2	A.W. Chesterton Co. Inc.	U.S.A.	1
Durabla Canada Ltd.	Gaskets		11		U.S.A.	
The Flintkote Co. of Canada Ltd.	Joint compound		13	Genstar Ltd.	Belgium	113
Garlock of Canada	Braids and sheets	19.1	50	Colt Industries	U.S.A.	8

Table 6.1 (continued)  
Ontario Asbestos Product Manufacturers  
(1981 Data Except as Noted)

Company	Product	Assets (\$ Millions)	Workers Under Surveillance, 1980*	Name	Parent Company		
					Country	% Owned	Number of Firms in Family**
Hill Machine and Asbestos			11				
Inmont Presstite Ltd.	Sealant	1.7	7	United Technologies Corp.	U.S.A.	99.2	21
Insul Coustics			NA				
Johns-Manville Canada Inc.***	A/C pipe	360 (1979)	500	Johns-Manville Corp.	U.S.A.	100.0	8
PRC Chemical Corp. of Canada Ltd.	Sealants	4.9	25	Products Research and Chemical Corp.	U.S.A.	100.0	3
Ranger Safety Products	Asbestos cloth, gloves		19				1
Raybestos- Manhattan (Can.) Ltd.	Friction materials	10.3	126	Raybestos- Manhattan Inc.	U.S.A.	99.2	7
Reichhold Ltd.	Mouldings		16	Reichhold Ltd.	Canada		
Relmech Mfg. Ltd.	Electric insulators		38				
Scott Laboratories	Filter pads		10				

**Notes:** \*Workers under surveillance by the Ministry of Labour's Occupational Health Branch.

\*\* In Canada excluding listed company.

\*\*\* Not active in asbestos product manufacture in 1981.

<sup>1</sup>NA means data not available.

SOURCE: Statistics Canada, Ontario Ministry of Labour, *Moody's Industrial Manual*.

\$731 million, equity of \$449 million, and \$69.8 million in profit on sales of \$870 million. These aggregate assets included the remaining assets of Bendix and Johns-Manville, both of which ceased asbestos operations in Ontario in 1980.

The third column of Table 6.1 which is headed "Workers Under Surveillance, 1980" can be taken, with the exception noted below, as a rough proxy for the number of workers in asbestos exposure employment in each firm during that year. The data were supplied to us by the Ministry of Labour and show the number of individuals under medical surveillance by the Ministry's Occupational Health Branch. The data are a proxy for asbestos exposure employment because ex-employees are not notified of the visits made by the Ministry's mobile x-ray units, save at Johns-Manville whose figure of 500 therefore overestimates the size of its workforce. (See Chapter 14, Section B.) With this exception, the data illustrate by firm the recent levels of asbestos manufacturing activity and prevalence of exposed employees. These evidently vary greatly, from 2 exposed employees at A.W. Chesterton to 480 at Bendix. Bendix, like Johns-Manville, ceased asbestos operations in 1980. It is apparent from Table 6.1 that, of the firms that remain active, friction product manufacturers account for about two-thirds of some 1,000 employees exposed to asbestos in Ontario manufacturing.

To gain a perspective on the changes in the structure of the industry over time, data were obtained from the Statistics Canada Census of Manufactures. For the years 1952 to 1969, the statistics were taken from an annual publication. However, for subsequent years statistics were developed specifically for this Commission. The criterion we adopted for defining membership in the industry was that 50% of the value of the total output of each firm be composed of products which were primarily composed of asbestos. This yielded a varying list of up to 10 firms, most of which are included in the list of Table 6.1. However, since employers have the discretion to classify their products as primarily composed of asbestos, or not, the accuracy of this industry definition is affected by the great latitude that firms enjoy in classifying their products. For instance, friction product manufacturers are included in this industry, although their final products may contain as little as 10 to 25% asbestos by weight. Table 6.2 shows that the industry experienced significant changes in the last decade. In 1980, the industry was composed of 10 firms and had shipments and revenues of asbestos products and non-asbestos products valued at \$109 million. This represents a 62% nominal increase in the 6-year period from 1974 to 1980, and a 9.6% decrease in real terms after adjusting for inflation.<sup>4</sup> The total nominal value of asbestos products (not shown in Table 6.2) rose by \$32.7 million or 96% in the same period. Part of this increase is undoubtedly at-

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<sup>4</sup>This index is based on price trends experienced by asbestos-cement products and friction products which amounted to a 79% increase between 1974 and 1980.

tributable to the change in the number of establishments in 1979. However, the increase also reflects the changing composition of the products manufactured by the industry; between the years 1974 and 1980, the value of friction products produced in Ontario increased by 300%, while in the same period the value of goods produced in the asbestos-cement products and asbestos tile categories declined by 19%. The reduction in manufacturing activity in the asbestos-cement product category caused consumption of crude asbestos in the industry to fall dramatically in a 6-year period. In 1974, the industry consumed 16.1 thousand tons of asbestos fibre with the value of \$4.1 million. However, by 1980, the quantity of asbestos declined by 50% to 8,000 metric tons with a value of \$4.0 million, reflecting a decline in the asbestos-cement product category. Asbestos represents a smaller percentage of total product value in friction products than in asbestos-cement, so the growth in friction products did not offset the contraction of activity in the asbestos-cement product sector. Behind the contraction of the asbestos-cement product sector evidenced in Table 6.2 lies the closure of the Johns-Manville Canada pipe operation in 1980 and the reduction in demand for asbestos-cement products by the depressed domestic and international construction industries.

It is possible that in addition to the general decline in activity in the construction sector, the reduced demand for asbestos-cement products is also a function of the increasing concern with the health effects of asbestos and the availability of cost- and performance-competitive substitute materials. The increase in friction product activity in Ontario may perhaps be attributable to the growing reliance of U.S. brake manufacturers on their Canadian operations to escape from the burgeoning number of asbestos-related tort claims being brought by workers suffering asbestos disease in the United States.

Professor Gordon M. Bragg conducted a survey for this Commission of the 23 firms listed in Table 6.1, gathering data which are in general agreement with the principal statistics from Statistics Canada reported in Table 6.3. Professor Bragg reported asbestos use by the firms in Ontario, not including Johns-Manville, for the year 1980 as shown in Table 6.4.

The dominance of friction products manufacture over the rest of the industry is clear as friction products account for over 50% of asbestos use in 1980. However, five years earlier the asbestos use by friction manufacturers was dwarfed in comparison to Johns-Manville's consumption: fully 75% of the total asbestos input to the Ontario industry was consumed at its plant.

Included in Professor Bragg's survey were responses to questions concerning the competitive conditions under which the asbestos products manufacturers in Ontario operate. Of the 10 firms which responded to the question concerning competition in Ontario, elsewhere in Canada, in the

Table 6.2  
Principal Statistics, Asbestos Manufacturing: Ontario\*

	1952	1956	1960	1964	1969	1974	1977	1979	1980
Number of establishments	8	8	8	8	7	9	9	10	10
Value of shipments (\$ Millions)	NA	NA	12.6	22.1	28.5	67.4	79.4	113.8	109.3
Manufacturing value added (\$ Millions)	NA	9.8	7.2	13.0	18.0	32.2	41.3	63.4	57.5
Total value added (\$ Millions)	NA	NA	NA	13.3	19.1	35.5	41.5	66.9	58.2
Quantity of asbestos fibre (000 metric tons)	NA	NA	NA	NA	NA	16.1	12.5	13.4	8.0
Value of asbestos fibre (\$ Millions)	NA	NA	NA	NA	NA	4.1	6.6	6.9	4.0
Employees administration	423	785	784	237	366	383	319	375	385
Employees production				938	923	1,389	1,199	1,345	1,195
Total salaries and wages (\$ Millions)	1.4	3.3	3.6	NA	9.8	18.2	21.4	26.7	27.3

**Note:** \* Industry includes only firms for which over 50% of total product value is products containing asbestos.

SOURCE: Statistics Canada.

Table 6.3  
Principal Statistics, Asbestos Manufacturing: Canada\*

	1952	1956	1960	1964	1969	1974	1977	1979	1980
Number of establishments	17	16	17	16	15	12	12	16	16
Value of shipments (\$ Millions)	19.6	34.2	29.4	43.0	50.3	112.1	135.3	193.3	184.0
Manufacturing value added (\$ Millions)	NA	18.4	15.8	24.9	31.1	52.2	66.0	96.7	85.7
Number of production employees	1,826	2,249	2,086	2,570	2,596	2,091	1,961	2,123	1,835
Quantity of asbestos fibre (000 metric tons)	44.6	72.8	54.3	60.7	67.6	50.2	47.4	55.3	36.7
Value of asbestos fibre (\$ Millions)	4.0	5.4	4.9	5.3	3.8	11.1	17.0	21.0	15.1
Average weekly earnings (\$)	NA	71.13	79.19	94.97	128.93	176.46	255.74	305.14	321.66

**Note:** \* Industry includes only firms for which over 50% of total product value is products containing asbestos.

SOURCE: Statistics Canada.

**Table 6.4**  
**Asbestos Use in Ontario Manufacturing**

<b>Products</b>	<b>Asbestos Used (Metric Tons/Year)</b>
Friction products	4,500
Floor tiles	1,000
Gaskets and packings	1,250
Caulking, sealants, coatings, and paints	600
Plastics	400
Cylinders	180
Insulators	100

SOURCE: Gordon M. Bragg, *The Technical Feasibility and Cost of Controlling Workplace Exposure to Asbestos Fibres*, Royal Commission on Asbestos Study Series, no. 7 (Toronto: Royal Commission on Asbestos, 1982), p. 7.

United States, or in the world, seven reported competition from the U.S. and three from other foreign countries. Vagt has reported that most manufactured asbestos products from other countries face a most favoured nation tariff of 11.9% (United States, West European countries), a general tariff of 25% (East European countries), or a general preferential tariff of 7.5% (underdeveloped countries).<sup>5</sup> Products made from crude asbestos of British Commonwealth origin are free under the British Preferential Tariff. Thus, it seems plausible that Canadian manufacturers of friction products must compete openly with each other and with any other U.S. firm, given the trade arrangements of the auto pact. The floor tile, gaskets and packing, caulking, sealants, coatings, and paints, and the plastics sector seem to face some domestic competition, and U.S. competition which is limited only by the tariff.

The Bragg survey enquired about the anticipated demand for asbestos fibre in the next 10 years. Apart from the friction product manufacturers, most companies responding expected that their use of asbestos in product manufacture would be discontinued by 1987. Furthermore, most of these manufacturers felt that they would produce a non-asbestos product with similar cost and performance characteristics which would substitute for the asbestos product. However, none of the friction product manufacturers, which constitute the largest segment of the Ontario asbestos manufacturing industry, foresaw their use of asbestos being curtailed by 1987.

The declining importance of asbestos as an input for non-friction product manufacturers was also confirmed by the Ministry of Labour investigation of asbestos users. Of the firms which were under surveillance by the Occupational Health Branch for asbestos use during the 1970s, 21% had by the end of the decade discontinued their use of asbestos as an input.

## B.2 Asbestos in Canada

How does the structure and activity of the Ontario manufacturing industry compare to that of the Canadian asbestos manufacturing industry as a whole? Employing the same method that was used to generate Table 6.2, Statistics Canada provided primary statistics for the Canadian asbestos manufacturing industry as a whole. In 1980, the total asbestos input to Canadian manufacturing was 36.7 thousand metric tons, almost precisely the Vagt estimates. (See Table 6.3.) Six firms outside Ontario were considered asbestos product manufacturers, generating \$74.7 million in total shipments and revenues, not shown in Table 6.3. This amount constitutes 41% of the total Canadian shipments and revenues of \$184 million. However, the asbestos used by the six non-Ontario firms constituted 73%

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<sup>5</sup>G. Oliver Vagt, *Asbestos* (Hull, Quebec: Supply and Services, 1980), p. 11.

of the total asbestos input in the entire industry. Again, this disparity may be traced to the concentration of the Ontario firms in friction products manufacture, while the non-Ontario firms were involved primarily in activity in the asbestos-cement pipe and building products sector.

While Ontario's involvement with asbestos is overwhelmingly as a manufacturer and consumer of asbestos products, other provinces are active not only in asbestos products manufacture, but in production of crude asbestos as well. World production of asbestos was about 5 million metric tons in 1980, of which about 90% was chrysotile.<sup>6</sup> In 1980, Canada shipped 1.335 million metric tons of chrysotile valued at \$642 million. Approximately 88% of this production was from Quebec, 7% from British Columbia, and 5% from Newfoundland.<sup>7</sup> Vagt showed Canadian asbestos consumption at 0.7% of world consumption, or approximately 36,000 metric tons.<sup>8</sup>

Canadian imports and exports of asbestos and asbestos products are shown in Table 6.5. During the last few years, Canada has imported considerable quantities of manufactured asbestos products including brake linings, packing materials, textiles, clutch facings, and asbestos-cement building materials. While a breakdown of asbestos products imported into Ontario is not available, we have identified the amount of South African asbestos, presumably crocidolite, that has been imported into Ontario. In 1979, this was 209 tons; in 1980, 230 tons; and in 1981, none. It is believed that the cessation of crocidolite importing into Ontario after 1980 is a reflection of the closing of the Transite pipe section of the Johns-Manville plant in Scarborough, which was a major user of crocidolite.

Table 6.5 also shows exports of asbestos fibre and products from Canada. The export of brake linings is about three-quarters the imports of those linings, reflecting the two-way trade with the United States occurring under the auto pact. The most important single manufactured product that is exported is asbestos-cement building materials valued at \$16.9 million in 1981.

The structure of Canadian asbestos manufacturing can be compared with that of the U.S. industry. Principal statistics on the asbestos manufacturing industry in the United States indicate total shipments and revenue of \$1,029.9 million U.S. (\$1,203.9 million Canadian, 1980). Of that amount 34.3% of the shipments and revenues accrued to friction products manufacture, 32.9% to asbestos floor tiles, and 31.3% to asbestos textiles, insula-

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<sup>6</sup>Ibid., p. 7.

<sup>7</sup>Ibid., p. 1.

<sup>8</sup>Ibid., p. 7.

Table 6.5  
Canadian Trade in Asbestos Fibre and Asbestos-Based Products  
(\$ Millions — Current)

Imports		1972	1974	1977	1979	1980	1981
Number	Description						
47420	Asbestos textiles	1.1	3.0	3.9	2.8	2.4	1.9
47424	Asbestos packing	1.1	1.9	2.1	2.9	3.2	3.5
47437	Asbestos brake linings	4.9	5.3	4.6	7.8	6.6	8.3
47438	Asbestos clutch facings	0.6	1.4	1.3	1.7	1.6	1.5
47454	Asbestos pipe cover	0.2	0.1	0.1	0.03	0.06	0.05
47456	A/C board/sheets	0.8	0.7	0.5	0.6	0.8	0.5
47469	A/C building materials	3.8	8.2	5.9	4.5	3.5	2.2
47499	Asbestos basic products	1.9	2.6	3.8	6.1	5.2	3.5
27149	Milled asbestos fibres			2.0	1.0	0.9	0.7
Exports							
Number	Description						
23110	Asbestos crude	0.132	0.08	0.003	0.012		0.026
22120	Asbestos milled fibres, Group 3	13.7	21.9	27.6	32.0		18.8
27130	Asbestos milled fibres, Groups 4 and 5						
27140	Asbestos shorts, Groups 6-9	156.6	227.8	393.0	465.0		424.4
47420	Asbestos textiles	64.7	89.5	132.9	155.6		131.6
47440	Asbestos brake linings		3.2	1.2	6.4		4.0
47469	A/C building materials	0.8	1.3	3.3	3.4		6.3
47499	Asbestos basic products	2.2	5.2	15.0	16.8		16.9
		2.4	3.5	5.7	10.1		9.4

SOURCE: Statistics Canada, Asbestos Mines: Mineral Statistics.

tion, and asbestos-cement products.<sup>9</sup> In Ontario, by contrast, Professor Bragg has reported that 78% of the shipments and revenues of the asbestos industry accrued from friction products manufacture.

### B.3 Ontario Worker Exposure to Asbestos

What worker exposure to asbestos fibres has resulted from asbestos product manufacturing in Ontario? Most available data were gathered after about 1970, when the membrane filter method was adopted for widespread use in monitoring occupational exposure to asbestos fibres. During the 1950s and 1960s, the Bausch and Lomb dust counter was used along with the Greenburg-Smith impinger, both of which measure dust levels in millions of particles per cubic foot. Very limited data indicate that manufacturing dust counts measured by the Bausch and Lomb dust counter averaged between 10 and 25 million particles per cubic foot (mppcf), with a range of values as high as 50, 75, or even 100 million particles per cubic foot in some samples. Particle counts taken with the midget impinger during the 1950s and 1960s averaged generally between 4 and 10 million particles per cubic foot, with the maximum concentration in individual samples ranging to 20, 30, or as much as 60. (See Table 6.6.) One source in 1958 produced an average of 32 million particles, with the highest single sample reading 134 million particles using the midget impinger. Table 6.6 summarizes the midget impinger data for firms producing friction products, asbestos-cement (A/C) pipe, and miscellaneous products.

By 1970, the particle counts using the midget impinger were declining, and this measurement was replaced by the membrane filter method which measures the concentration of fibres. Table 6.7 shows average annual fibre counts using the membrane filter method in five friction products plants, three gasket plants, and one asbestos-cement pipe plant in Ontario. Each average is an average of all area and personal samples in all plants monitored during that year. The percentage of all samples in which the count exceeded 2 fibres per cubic centimetre (f/cc) is also shown. The great variability in data such as these is discussed in a study prepared for this Commission by Dr. Eric J. Chatfield and in Chapter 7, Section B of this Report.<sup>10</sup> These data show generally declining fibre counts during the 1970s, with many plants achieving levels well below 1 fibre much of the time in the late 1970s. It appears that friction products have higher dust levels than either gasket and packing or asbestos-cement operations.

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<sup>9</sup>Telephone communication between Mr. John Ambler, U.S. Bureau of Census, Washington, D.C. and Royal Commission on Asbestos Staff. Data are for Standard Industrial Classification 3292.

<sup>10</sup>Eric J. Chatfield, *Measurement of Asbestos Fibre Concentrations in Workplace Atmospheres*, Royal Commission on Asbestos Study Series, no. 9 (Toronto: Royal Commission on Asbestos, 1982), sec. 2.4.

Table 6.6  
Summary of Asbestos Dust Levels in Ontario Manufacturing Measured by Midget Impinger\*  
(Millions of Particles Per Cubic Foot)

Year	Friction Products		Miscellaneous		A/C Pipe	
	Average	Range	Average	Range	Average	Range
1956					8.5	1.1-60
1958			32	2.1-134		
1961					7.8	0.4-28
1965	1.2	0.3-3.5				
1967	5.7	3.1-8.4				
1968					3.4	1.5-5.8
1969					7.9	6.5-9.2
1971			7.4	7.4	5.8	2.2-20
1972	11.7	6.0-30	2.0	1.0-3.7	2.2	0.5-5.8
1973					2.8	0.5-8.7
1974	4.2	1.4-7.6			4.4	1.5-32

Note: \* Different plants may be included in the measurements of different years.

SOURCE: Ontario Ministry of Labour, Occupational Health and Safety Division.

Table 6.7

**Summary of Asbestos Dust Levels in Ontario Manufacturing  
Measured by Membrane Filter (Fibres per Cubic Centimetre)**

Product:	A/C Pipe									
	Friction Products*		Gaskets and Packings*		Ministry Data*		Company Data (Personal Samples)**			
	Average	% Samples Greater than 2 f/cc***	Average	% Samples Greater than 2 f/cc***	Average	% Samples Greater than 2 f/cc***	Wet End % Samples Greater than 2 f/cc***	Finishing End % Samples Greater than 2 f/cc***		
Year										
1969	1.9	33	4.3	50	5.7	40	89	92		
1970	4.1	75	NA†	NA	NA	NA	62	51		
1971	3.6	63	1.2	0	1.0	0	46	31		
1972	3.6	73	2.2	40	1.1	3	67	35		
1973	1.6	30	NA	NA	1.7	25	8	8		
1974	1.3	21	NA	NA	1.6	51	18	6		
1975	1.3	15	1.1	24	0.6	0	16	4		
1976	1.5	15	NA	NA	0.6	10	0	2		
1977	2.9	36	1.2	0	0.5	0	0	0		
1978	2.5	43	2.8	22	0.7	11	0	4		
1979	1.6	23	0.4	0	0.3	5	0	0		
1980	1.4	20	0.5	6	0.1	0	NA	NA		
1981	0.7	10	0.1	0						
							Plant closed			

**Notes:** \* Ontario Ministry of Labour, Occupational Health and Safety Division.

\*\* From Johns-Manville company records.

\*\*\* In 1972, the Ontario Ministry of Labour began to apply a guideline of 2 f/cc.

† NA means data not available — no readings taken.

SOURCE: See Notes \* and \*\* above.

Unfortunately, it is not possible to convert the earlier particle counts to an equivalent fibre count using today's measurement technology in a general way, although some comparison studies have been conducted.<sup>11</sup> Thus, we cannot be sure how today's exposure levels compare with those of the 1950s and 1960s. While there is nearly universal agreement that the recent fibre measurements reflect dust particle levels far less than those prevailing in the 1950s, considerable disagreement remains as to what those levels actually were.

Dr. Murray M. Finkelstein reviewed the history of the Transite pipe section of the Johns-Manville plant and concluded that as compared to the years 1969–1970, exposures were 30% higher during 1955 through 1962, and were twice as high during 1948–1954.<sup>12</sup> By the late 1970s, exposures were reduced to generally less than 10% of the exposures of 1969–1970, depending on the work station. This yields estimated average exposure levels in three areas of the plant of 40, 16, and 8 f/cc in 1948–1954; 26, 10, and 5 f/cc during 1955–1962; and 20, 8, and 4 f/cc by 1969–1970. Finkelstein noted that all of these estimates are subject to considerable uncertainty, perhaps erring by a factor of 3 or 5 either way.

Rajhans, Bragg, and Morton surveyed Ontario Ministry of Labour records of membrane filter fibre counts at one asbestos mill, three friction product plants, and one asbestos-cement pipe plant.<sup>13</sup> The average readings for all plants declined from almost 4 f/cc in 1972 to about 1 f/cc in 1974, then rose close to 2 f/cc by 1976. All brake plants produced averages below 1 f/cc at some time, but two of the plants experienced considerable increases in fibre levels within a year after low readings were achieved. This survey concluded that a 2 f/cc standard was achievable in practice in 1977.

## C. Technical Feasibility and Cost of Dust Control

### C.1 Control Methods

Professor Bragg identified some basic methods of controlling the asbestos fibre exposure of workers.<sup>14</sup> The most important methods are:

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<sup>11</sup>See the discussion of early fibre estimates in Chapter 5, Section D, and of measurement techniques in Chapter 7, Section B.

<sup>12</sup>Murray M. Finkelstein, "Asbestosis in Long-Term Employees of an Ontario Asbestos-Cement Factory," *American Review of Respiratory Disease* 125 (1982): 497. See also, Chapter 3, Section A.3 of this Report.

<sup>13</sup>Gyan S. Rajhans, Gordon M. Bragg, and J. Stewart Morton, "A Review of Asbestos Exposure in Ontario," *American Industrial Hygiene Association Journal* 39 (September 1978): 767–771.

<sup>14</sup>Gordon M. Bragg, *The Technical Feasibility and Cost of Controlling Workplace Exposure to Asbestos Fibres*, Royal Commission on Asbestos Study Series, no. 7 (Toronto: Royal Commission on Asbestos, 1982), p. 34.

*Substitution* — Replacing the asbestos with a non-asbestos substitute in a product is a certain way of eliminating asbestos fibre exposure. A later section of this chapter will discuss the feasibility of substitution for asbestos in various products, and the possible health effects of substitutes.

*Process Alteration* — Some processes are inherently less dusty than others. Thus, for example, cutting asbestos-cement sheet with a knife creates less dust than sawing the same sheet.

*Isolation and Enclosure* — Placing a barrier between the worker and the source of asbestos dust, particularly by building an enclosure around the machine, process, or operation, can be highly effective in reducing the exposure of the worker. Local exhaust is usually used to prevent fibre release from the enclosure. Hazards still exist, however, when the enclosure is opened for feeding the machine or for maintenance.

*Wet Methods* — Soaking the asbestos product in a liquid, or spraying water on a cutting process, can dampen the fibres and thus prevent them from becoming airborne. Wet methods are highly effective at reducing dust, but may adversely affect the manufacturing process for some products.

*Local Exhaust* — Exhausting contaminated air from the region immediately around the process is the traditional method of dealing with asbestos dust problems. The exhausted air must be cleaned, typically in a bag-house, after which it may be re-used or blown outside. Moving this air, and warming the replacement air in winter, are costly in the Canadian environment.

*Personal Protection Devices* — For asbestos, the basic personal protection device is a respirator. While some models are quite effective, they are uncomfortable and inconvenient to wear for long periods of time.

*Housekeeping* — Regular careful cleaning of the workplace, including vacuuming rather than sweeping dust from floors, walls and ceilings, cleaning up spills when they occur, and maintenance of dust control equipment, can considerably reduce fibre levels, particularly when ventilation has already achieved reasonably low levels.

*Monitoring Alarms* — While some hazardous substances can be monitored continuously, so that any escape can trigger an alarm that will allow employees to avoid the substances, such monitoring is difficult and expensive for asbestos fibres, and there are serious problems with accuracy of the instrument. (See Chapter 7, Section B of this Report.)

*Training* — Where proper work practices and housekeeping are important for controlling dust levels, the training of employees in these techniques may significantly reduce employee exposures.

## C.2 Feasibility of Control

The feasibility and cost of controlling fibre levels in the workplace can be evaluated by identifying operational processes where fibres may be released, and dealing with each of these separately. An asbestos product manufacturing plant will typically include a number of different processes, each of which may cause greatly different fibre releases. Since each process must be individually controlled, it is more accurate to analyze the processes separately than to compare one entire plant, such as a brake plant, with, for example, an asbestos-cement pipe plant.

Professor Bragg identified nine major operational processes that are typically used in Ontario asbestos manufacturing plants. These are listed in Table 6.8 along with the typical fibre levels found in Ontario in 1980 and 1981. Table 6.8 demonstrates that debugging is the dirtiest process, given current control technology, while cutting is relatively clean. For all of these processes, a change in the control technology could presumably change the fibre levels that are experienced by the operator.

Professor Bragg discussed the feasibility of controlling fibre levels in seven of the processes listed in Table 6.8. In doing so, he noted that there is considerable variability in control practices from one plant to another, depending in part on the level of engineering expertise within a particular company. He stated:

The detailed application of engineering controls requires an intimate knowledge of ventilation practices, plant processes, and air pollution technology. We would estimate that there are fewer than twenty-five people within the province who could be considered truly expert in this field, most of whom are employed in specific plants. The others work in government or as consultants. In addition, the person must have an intimate knowledge of each plant to which he intends to apply controls. As may be suspected, the larger the plant, the higher the probability that this expertise exists within the company. The result of this process is that some companies have achieved higher control capability with less money and less interference with processes than others. In addition, we have found small manufacturing facilities with no engineering skills and little knowledge of control processes who are spending money but achieving very poor control. We see this latter problem with smaller industries as an important aspect in achieving province-wide controls.<sup>15</sup>

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<sup>15</sup>Ibid., p. 49.

**Table 6.8**  
**Typical Ontario Processes and Fibre Levels\***

Operations Typical to Ontario Asbestos Industry	Typical Fibre Levels Found
	(f/cc)
Debagging	0.5 - 8.0
Pressing or forming	0.5 - 3.0
Grinding	0.5 - 5.0
Drilling	0.5 - 2.0
Cutting — Press	0.1 - 0.7
— Hand	0.2 - 2.0
Braiding	0.1 - 3.0
Spinning	0.1 - 3.0
Twisting	0.1 - 3.0
Sheeter operation	0.4 - 2.0

**Note:** \*Based on 1980 and 1981 Ontario Ministry of Labour reports.

**SOURCE:** Gordon M. Bragg, *The Technical Feasibility and Cost of Controlling Workplace Exposure to Asbestos Fibres*, Royal Commission on Asbestos Study Series, no. 7 (Toronto: Royal Commission on Asbestos, 1982), Table 3.3, p. 47.

Professor Bragg also pointed out that a given fibre level cannot be achieved all the time, since even a clean process may occasionally produce high fibre levels.<sup>16</sup> High fibre levels are often released during the maintenance of machinery, failure of machinery, failure of air-conveying systems, worker sabotage of ventilation systems, improper usage of equipment, and high winds affecting the air cleaning system. There is some ambiguity about whether the fibre levels referred to in the Bragg study should be interpreted as average exposure levels, or as achieving compliance with a control limit, which would imply average exposures of half the control limit. In his discussion of control costs, the proper interpretation is as follows: references to fibre levels of 2, 1, and 0.5 f/cc are references to compliance with control limits of these amounts, so that average exposures are half the stated amounts; references to fibre levels of 0.1 f/cc refer only to the average exposure, and do not assure that compliance with a 0.1 f/cc control limit is possible. Professor Bragg's analysis can accordingly be seen as examining compliance with control limits of 2, 1, 0.5, and 0.2 f/cc and achieving average exposures of 1, 0.5, 0.25, and 0.1 f/cc.

Finally, Bragg concluded that higher levels of control are not always more expensive. For example, some enclosures use very little ventilating air, so the added expense of enclosure can, to some extent, be balanced against the decreased use of ventilating air.

Emptying asbestos out of bags, or *debagging*, is one of the most difficult processes to control. In this process the operator slits open 2- or 3-foot long plastic bags of asbestos and dumps or shakes the asbestos into a drum or hopper. A large working area is needed to accommodate the large bags. Since the working area is large, a large amount of ventilation air must be used. The empty bag may still contain considerable amounts of asbestos fibre, so placing the bag in a refuse container may also release a lot of dust. While several automated debagging machines are available, they cost about \$50,000 each, and Bragg had serious doubts about their reliability and effectiveness.<sup>17</sup> He reported that none of these machines is in use in Ontario, although they would be necessary to reach 0.5 f/cc.

Professor Bragg reported that *grinding* and finishing produce large amounts of fibrous material presenting considerable control problems. Proper positioning of the air intake is imperative if 0.5 f/cc is to be achieved. Special machine designs dedicated to a specific grinding operation are necessary to achieve low fibre levels.

The control of fibre releases from *drilling* can be examined in the control of friction products manufacture. Drilling holes in the brake pads

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<sup>16</sup>Ibid., pp. 49-50.

<sup>17</sup>Ibid., pp. 58-59.

or linings is commonly done with a group of synchronized pneumatic drills. Good ventilation will ordinarily hold fibre levels to around 1 f/cc. Poor ventilation can allow the fibre levels to exceed 2 f/cc. If exhaust from the pneumatic system is allowed to blow on the ensuing dust, then fibre levels can rise well above 5 f/cc. Control to the 1 to 2 f/cc level commonly requires suction around the bottom of the drills to collect chips and dust and frequent vacuum cleaning of spilled material. Enclosing this process will require a device for feeding the brake linings or pads into the enclosure. Depending on the degree of automation this may require opening of the enclosure to feed-in new parts and to remove completed parts. Bragg estimated that a well-designed and enclosed automated process should reduce fibre levels down to 0.1 f/cc or lower.<sup>18</sup> For a semi-automated process where handloading is required, the fibre levels in the room would be below 0.1 f/cc during operation, and a sufficiently large exhaust would probably maintain this level during the opening of the enclosure. Enclosing a semi-automated process where handloading is used would result in a loss in output per worker in the order of 5 to 10%. The machine would remain as productive, but the amount of labour required would increase by this amount.

Another process used in Ontario is the *cutting* of gasket material. Professor Bragg reported that hand-cutting of asbestos gaskets for custom installations results in a very small quantity of dust, usually around 0.1 to 0.7 f/cc.<sup>19</sup> Thus, no controls are required unless it is desired to reduce average exposures below about 0.5 f/cc. Cutting these gaskets on a table whose surface has a fine array of holes, and pulling air downwards through the table and away from the worker's face, would almost certainly provide extremely low dust levels. A more difficult control problem is presented by the sawing of large sheets of asbestos-cement or asbestos-reinforced plastic for laboratory table tops and electrical and heat insulator applications. Local exhaust provided around the saw blade and the cut will keep fibre levels down to 2 to 4 f/cc if very high rates of airflow are maintained. Another control method for this type of process is wet-cutting, in which a spray of water is continually directed at the cutting area. However, the slurry which results is asbestos-contaminated. If this water dries in floor cracks and in parts of the machinery, then a fibre-contaminated cake is produced. Any disturbance of this cake will result in fibre contamination of the air. Wet-cutting could not produce fibre levels below approximately 0.5 f/cc. If 0.1 f/cc is desired, the only satisfactory procedure would be to provide the operator with personal protective devices.

We do not believe that any manufacturers in Ontario currently *spin* asbestos yarn from raw asbestos fibre. However, some plants do braid or

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<sup>18</sup>Ibid., pp. 55-56.

<sup>19</sup>Ibid., p. 57.

*twist* yarn from outside the province into a rope-like material for packing bearings. Generally, the yarn is treated with various substances such as graphite and Teflon before braiding, which reduces dust release in the braiding process. The dust level, however, depends upon the stage of manufacturing at which the yarn is coated. Professor Bragg concluded that a major reduction from 2 f/cc to approximately 0.1 f/cc may be achieved in the braiding and twisting operation through the use of good enclosures and exhaust systems. He did not express confidence that a 0.1 f/cc standard could be met all the time in this process, but rather that this level could be approached in most plants with appropriate ventilation and enclosure.

The *sheeting* process consists of mixing some wet and dry ingredients, including asbestos fibres, and then shovelling the resulting mud-like material into a sheeting mill. The sheeting mill rolls the material into a sheet of a desired thickness, after which some of the moisture is squeezed out and the sheet is cured and hardened. Because the recipe generally includes a large quantity of volatile solvents, the process requires a high degree of local exhaust in order to control the vapour from these solvents. This ventilation also controls asbestos fibre levels. Bragg concluded that a major reduction from 2 f/cc to approximately 0.1 f/cc may be achieved with the use of good enclosure and exhaust systems. Again, Bragg was not confident that a 0.1 f/cc control limit could be consistently met, but rather that exposure levels could be brought to approximately 0.1 f/cc most of the time.

In summary, Bragg found that current Ontario fibre levels in manufacturing are low compared to fibre levels of a decade or more in the past. He also found that further reductions in fibre levels are possible for many processes. However, as actual fibre levels are reduced below 1 f/cc, it becomes more difficult to measure them accurately and more difficult to control them reliably. Thus, success in fibre control leads inevitably to problems of measurement and enforcement, which will be discussed in Chapter 7, Section B of this Report.

### C.3 Cost of Control: Three Hypothetical Cases

The information available on the cost of controlling asbestos fibre exposure in the workplace comes from some American studies, and the work by Bragg. Since Bragg has reviewed the American studies, and used them as a source of some input data to his own analysis, we will refer primarily to the Bragg study itself. We will review the cost of controlling worker exposures to asbestos in three types of plants that have counterparts in Ontario: brake manufacture, gasket manufacture, and a small plant whose product line includes both asbestos-containing and non-asbestos gaskets. In each case, the plant is hypothetical, but permits the calculation of typical costs of achieving various control limits.

**(a) Brake Manufacture**

The first costing exercise involves a hypothetical plant manufacturing disc brake pads and/or shoes for drum brakes. Professor Bragg relied upon the experience of the Ontario brake plants in controlling dust to 1980 levels, and on his calculations of the component costs for dust control systems to produce still lower levels of dust.<sup>20</sup> Rather than calculating the cost for an existing brake plant, he used as an example a hypothetical plant employing about 30 production workers, with one mixing machine, and ten machines each in the preform press, drilling, and grinding/finishing stages. By using this hypothetical plant, it is possible to generate a representative cost estimate for the industry without becoming too complex or specific to a particular plant. Table 6.9 shows the control technology needed and the cost of that technology for the four major processes in the hypothetical brake plant, to comply with control limits of 2, 1, 0.5, and 0.2 f/cc.

While costs are presented separately for each process, in some cases this cost allocation was arbitrary, since major costs, such as the cost of the blower and bag-house, were shared among all processes. Table 6.9 shows the capital cost of the equipment for each process, the annual operating cost including labour, materials, and reduced productivity, the number of operators, and the total annual cost per operator. Actual control costs will depend upon the size of the plant and its age, the type of equipment currently installed, the skill and expertise of the operator of the plant, and other factors, so that these estimates cannot necessarily be applied directly to any particular manufacturing plant.

Compliance with a 2 f/cc control limit is estimated to require a \$94,920 capital investment and a \$100,602 per year operating cost, for an average total cost per operator of \$4,083 per year. The data on worker exposure shown above in Table 6.7 suggest that by 1980 and 1981 most brake manufacturing plants exceeded a 2 f/cc level only 10 to 20% of the time. Thus, the industry was close to compliance with a 2 f/cc control limit. Therefore, we may assume that the \$4,083 per operator for achieving a 2 f/cc control limit has already been spent. Moving to a 1 f/cc control limit requires a total expenditure of \$5,432 per year per operator, an increase of \$1,350 per operator per year, and Bragg regarded the 1 f/cc control limit as difficult to meet in the debagging operation. Compliance with a 0.5 f/cc control limit costs \$7,954 per year per operator, an increase of more than \$2,500 per year per operator over the cost of achieving 1 f/cc. Once again, Bragg was not at all optimistic that this level could in fact be complied with without respirators for debagging.

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<sup>20</sup>Ibid., sec. 4.2.

Finally, the cost estimate for 0.2 f/cc is a total capital cost of \$2.125 million, an annual operating cost of \$173,502, and an annual cost per operator of \$19,721, an increase of almost \$12,000 per year per operator over the cost of complying with a 0.5 f/cc control limit. Professor Bragg was not convinced that compliance with the 0.2 f/cc control limit could be achieved in practice throughout most of the plant on a regular basis.

### **(b) Gasket Manufacture**

The second hypothetical costing exercise involves a manufacturer of gaskets and braided packings. The manufacturer is assumed to braid asbestos yarn into packing rope, and to manufacture gasket sheeting and then stamp gaskets out of that sheeting. For purposes of this costing study, a hypothetical plant employing 30 people and consisting of a compounding or mixing station, a sheeting mill, ten braiding/twisting machines, and a spooling station was analyzed. The costs of complying with a 2 fibre control limit and a 0.2 fibre control limit only were estimated. The results are shown in Table 6.10. While Table 6.10 shows the control technology and cost necessary to comply with a 0.2 fibre control limit in a hypothetical plant, Bragg was again not confident that this could be reliably achieved in practice.

One might therefore interpret these costs as the costs of reliably complying with or bettering a control limit of 0.5 f/cc, or as a cost of approaching, if not meeting, compliance with a 0.2 fibre control limit. Interestingly, while most of Bragg's concern about achieving low fibre levels was in the debagging and mixing operation, the major costs shown for complying with the 0.2 fibre limit in Table 6.10 occur at the braiding operation. The cost of approaching the 0.2 fibre control limit, at \$6,996 per operator per year, is only about \$1,800 greater than the cost of complying with the 2 fibre control limit. Fibre control in this industry is clearly less expensive than in friction products, judged by a comparison of the average total cost per operator per year for approaching a 0.2 fibre level in the two industries.

### **(c) Small Gasket Manufacture**

The third costing exercise is for a small manufacturer of gaskets, whose product line includes both asbestos-containing and non-asbestos gaskets. The plant includes two presses, two hand-cutting tables, and two sewing machines, employing eight production workers. The plant does not handle raw asbestos, but buys sheets of gasket material, so the dirtiest operations, bag-opening and mixing, are avoided. Even in the absence of control limits, fibre levels are in the 0.5 to 0.2 f/cc range. The hand-cutting operation is the only major contributor to airborne asbestos fibres. Professor Bragg concluded that controlling this operation by the use of special surface-exhausted tables can reduce levels to 0.2 f/cc near the cutting table.

Table 6.9  
Requirements for Control in Friction Products Manufacturing and Relative Costs  
(Costs in 1980 \$ Canadian)

Fibre Control Limit	Process	Description of Control	Capital Cost	Annualized Capital Cost	Annual Operating Cost	Number of Operators	Annual Total Cost per Operator*
2 f/cc	Storage, receiving, and mixing	Manual bag opener with local exhaust	\$ 12,600	\$ 2,362	\$ 7,924	2	\$5,143
	Preform and press	No local exhaust required	—	—	4,036	9	448
	Drilling	Minimal enclosure design with exhaust	41,160	7,715	44,321	9	5,782
	Grinding and finish	Minimal enclosure design with exhaust	41,160	7,715	44,321	9	5,782
TOTALS			\$ 94,920	\$17,792	\$100,602	29	AVERAGE \$4,083
1 f/cc	Storage, receiving, and mixing	Immediate bag repair; general housekeeping; manual bag opener with good hood or enclosure; increased face velocity	\$ 11,025	\$ 2,067	\$ 8,665	2	\$5,366
	Preform and press	Minimal local exhaust	32,393	6,071	28,710	9	3,865
	Drilling	Good enclosure surrounding workplace	47,784	8,957	45,978	9	6,104
	Grinding and finish	Full enclosure	59,202	11,097	45,978	9	6,342
TOTALS			\$150,404	\$28,192	\$129,331	29	AVERAGE \$5,432

Table 6.9 (continued)  
Requirements for Control in Friction Products Manufacturing and Relative Costs  
(Costs in 1980 \$ Canadian)

Fibre Control Limit	Process	Description of Control	Capital Cost	Annualized Capital Cost	Annual Operating Cost	Number of Operators	Annual Total Cost per Operator*
0.5 f/cc	Storage, receiving, and mixing	Immediate bag repair; general housekeeping; tighter enclosures about the entry port and debagger; larger general hood	\$ 128,951	\$ 24,170	\$ 32,098	2	\$28,134
	Preform and press	Full local exhaust	44,130	8,273	26,718	9	3,888
	Drilling	Full enclosure	65,926	12,357	57,343	9	7,744
	Grinding and finish	Full enclosure	65,926	12,357	57,343	9	7,744
	TOTALS		\$ 304,933	\$ 57,157	\$173,502	29	AVERAGE \$7,954
0.2 f/cc**	Storage, receiving, and mixing	Covered (protected) storage containers; increased floor space; fully automated debagger and mixing set with large exhaust hood	\$ 228,952	\$ 42,915	\$ 32,098	2	\$37,507
	Preform and press	Full enclosure	79,262	14,856	26,718	9	4,619
	Drilling	Full enclosure	141,207	26,468	57,343	9	9,312
	Grinding and finish	Full enclosure and perhaps redesign special equipment for specific finishing operations	1,676,150	314,178	57,343	9	41,280
	TOTALS		\$2,125,571	\$398,417	\$173,502	29	AVERAGE \$19,721

Notes: \* Annual Total Cost per Operator equals Annual Capital Cost plus Annual Operating Cost, divided by Number of Operators.

\*\* This level may not be achievable in practice.

SOURCE: Adapted from: Gordon M. Bragg, *The Technical Feasibility and Cost of Controlling Workplace Exposure to Asbestos Fibres*, Royal Commission on Asbestos Study Series, no. 7 (Toronto: Royal Commission on Asbestos, 1982), Table 4.2, pp. 68-69.

Table 6.10  
Requirements for Control in Gasket Manufacturing and Relative Costs  
(Costs in 1980 \$ Canadian)

Fibre Control Limit	Process	Description of Control	Capital Cost	Annualized Capital Cost	Annual Operating Cost	Number of Operators	Annual Total Cost per Operator
2.0 f/cc	Debag, mixing, receiving	Hooded debagging mixing stations	\$ 8,143	\$ 1,526	\$ 6,069	3	\$ 2,532
	Sheeting mill	Minimal hood design and flow rate	34,277	6,425	30,241	5	7,333
	Trimming tables	Minimal enclosure	—	—	4,036	6	673
	Braiding M/C	Minimal enclosure	97,802	18,332	56,446	10	7,478
	Spooling M/C	Canopy hood	7,071	1,325	6,069	1	7,394
TOTALS			\$147,293	\$27,608	\$102,861	25	AVERAGE \$ 5,219
0.2 f/cc*	Debag, mixing, receiving	Debagging with enclosure	\$ 6,897	\$ 1,293	\$ 4,552	3	\$ 1,948
	Sheeting mill	Large canopy hood at 130 ft/min face velocity	52,837	9,904	45,933	5	11,167
	Trimming tables	Complete (tight) enclosure	21,756	4,078	12,000	6	2,680
	Braiding M/C	Complete (tight) enclosure	120,241	22,538	68,969	10	9,151
	Spooling M/C	Better placement for particle capture; increased cfm	5,825	1,092	4,552	1	5,644
TOTALS			\$207,556	\$38,905	\$136,006	25	AVERAGE \$ 6,996

**Note:** \*This level may not be achievable in practice.

SOURCE: Adapted from: Gordon M. Bragg, *The Technical Feasibility and Cost of Controlling Workplace Exposure to Asbestos Fibres*, Royal Commission on Asbestos Study Series, no. 7 (Toronto: Royal Commission on Asbestos, 1982), Table 4.5, p. 79.

## C.4 Economic Impact of Control Costs

What are the economic consequences of the cost increases that may result from the requirement in one province of measures more strict than in other provinces, or in the United States, to protect the health and safety of workers? Any of three results is possible. First, manufacturers may raise prices and pass their increased costs fully on to consumers. Alternatively, manufacturers might pay lower wages to their workers, and thereby pass the costs back to those workers. Finally, prices and wages might remain unchanged, with investors in the industry absorbing all the costs through a lower rate of profit. In many cases, some combination of these three effects will result.

What determines the extent to which each effect occurs? The primary factor is the degree of competition in each market. If the product market prices are determined primarily by competition from firms outside the province, firms in the province have little ability to raise prices without losing markets to their outside competitors. If there is little or no competition from non-Ontario manufacturers for the market served by Ontario manufacturers, they may be able to pass on most or all of their cost increases to consumers. If the labour market is highly competitive, then wages cannot fall without current workers moving to other jobs, and difficulties occurring in recruiting new workers. On the other hand, if workers have few or no alternative places of employment, it may be possible to lower wages sufficiently to recoup the extra costs. Finally, if the shares of the firm are publicly traded, then in the long run the firm must pay its shareholders a market rate of return if it is to attract new capital. If the industry has been earning above-average rates of return, these may be driven down to the average, before difficulty arises in attracting new capital.

We have some information on the competitiveness of the markets for products of Ontario asbestos manufacturing firms. It was suggested earlier in this chapter that most Ontario manufacturers face some competition from other provinces and from the United States. For those plants, it could be assumed that significant price increases would be accompanied by significant losses in market share. If U.S. manufacturers abandon asbestos product lines in the future because of concern about tort lawsuits, then the effective degree of competition will be reduced, and the ability of Ontario manufacturers to raise their prices will be enhanced. Some product lines, however, face competition from other provinces, which might cause substantial erosion of market shares in the event of substantial price increases. If other Canadian provinces adopt regulations similar to those in Ontario, then the relative competitive position of Ontario versus other provinces should not be significantly affected, and passing costs on to consumers would be facilitated.

We have little data on the alternative opportunities facing workers in

the asbestos manufacturing firms of Ontario. Frequently, the skill level required of exposed workers is not high, so that they are not prevented from moving to other jobs by possessing skills that are specific to this particular activity. Some plants are located in large labour markets where alternative employment opportunities should exist, at least in good economic times. A few are located in small centres where one might anticipate that even in good times, alternative employment opportunities would be limited. Here, the ability of the firm to reduce wages to absorb cost increases would probably be greater than in plants located in large labour markets. Of course, to the extent that labour perceives more strict asbestos control standards as enhancing the quality of the workplace, then fibre control programmes should increase the supply of labour at any particular wage, or allow firms to lower wages slightly and still attract a sufficient pool of workers.

Most of the asbestos manufacturing firms in Ontario are related to large multinational corporations. Here it seems safe to assume that in the long run, rates of return below the return earned by other segments of the corporation would lead to a reduction or elimination of asbestos manufacturing. We have no way of knowing the extent to which Ontario asbestos manufacturing plants may currently generate above-average rates of return which would allow reduced earnings without reduced investment.

There are two comparisons that may be helpful in assessing the magnitude of control costs. First, we can compare the costs per year per operator per fibre with the wages of the operators themselves. Table 6.3 reports average weekly earnings in asbestos manufacturing in Canada of \$322 per week in 1980. If we multiply by 50 work weeks per year, we get an annual wage in 1980 of approximately \$16,000. By comparison, the cost of moving from 2 to 1 f/cc in the brake plant is \$1,349 per operator per year, representing 8% of the worker's wage. The 0.5 f/cc level costs \$3,871 more per year than the 2 f/cc level, or about 24% of the wage. Finally, the 0.2 f/cc level, if it could be achieved, would cost \$15,683 per operator per year more than the 2 fibre level, representing about 98% of the worker's wage. Thus, moving from 2 f/cc to 0.2 f/cc would be approximately as costly as doubling the wage rate of those operators who are directly exposed in the manufacturing process.

Suppose that the industry could pass these costs on entirely to their customers. What price increase would be required? We can only make rough estimates of the answer to this question. Table 6.2 shows that in 1980 the Ontario manufacturing industry as represented in that table employed 1,195 production workers. Let us suppose that all of these workers were employed in the friction products industry and that all of them were operators in the sense used by Bragg in his cost calculations. The total cost of control for the industry can be determined by multiplying the cost per year per operator by 1,195 operators. Thus, achieving the 1 f/cc level adds

\$1,349 per worker to the firm's cost, for a total of \$1.6 million. Since the industry's wage bill, shown in Table 6.2, is \$27.3 million, this should be a 5.9% increase in the total cost of employing and protecting these workers. Data from Statistics Canada show the value of asbestos products produced by the industry in 1980 at \$66.4 million. If prices were increased to generate an additional \$1.6 million of revenue, this would require a 2.4% increase in product prices.

Applying the same analysis to the 0.5 f/cc level yields a control cost of \$3,871 per operator per year, which would impose a total cost of \$4.63 million to protect 1,195 workers. This would raise the total wage bill by 17%, and would require that product prices be raised by 7% to cover the cost.

While these comparisons may be instructive, they are nevertheless crude. The data in Table 6.2 are from a variety of operations, not just brake plants, and other operations may be controlled at less cost than brake plants. Furthermore, not all hourly employees would be operators as defined by Bragg, and therefore the cost of controls for the industry may be considerably less than the estimates just presented. If half of the production employees were not operators, but were performing maintenance and other duties, then the industry costs we have just calculated would be overstated by a factor of 2. This analysis of control costs relies upon existing technology, which Bragg expects to be the predominant technology for the immediate future. It is entirely possible that in the future, advanced technology might reduce the costs below those found here. Automation might greatly reduce the number of exposed workers and in consequence reduce the cost of worker protection; however, it might also generate adverse employment effects. Finally, all costs will not necessarily be passed on to consumers. It is possible that some costs would be absorbed by labour in trading lower wages for better health and safety, and some might be absorbed out of the profit of the firms, if this still allows an adequate rate of return.

### **C.5 Marginal Cost of Control per Marginal Unit of Exposure**

Table 6.9 above presents detailed information on the costs of controlling fibre levels in a hypothetical brake manufacturing plant. These data are summarized in the annual cost per operator of achieving the various fibre levels. The calculations can be carried one step further to determine the cost per fibre per cubic centimetre of reducing operator exposure. This is the difference between the cost for any two fibre levels divided by the fibre reduction. If it costs \$1,000 to reduce exposure from 1 f/cc to 0.5 f/cc, the marginal cost per fibre would be \$1,000 divided by a 0.5 fibre reduction or \$2,000/f/cc. If it costs another \$1,000 to reduce the exposure from 0.5 f/cc

to 0.2 f/cc, the marginal cost per fibre would be \$1,000 divided by a 0.3 fibre reduction or \$3,333/f/cc. The same cost increment yields a marginal cost per fibre that is two-thirds greater because it achieves a fibre reduction only 60% as great.

The initial achievement of compliance with a 2 f/cc control limit (1 f/cc exposure) costs \$4,083 per year per operator. While we do not know what levels would exist in the absence of controls, Berry and Newhouse estimated that average fibre exposures in the Ferodo friction products plant at Derbyshire, England, were often around 5 or 10 f/cc.<sup>21</sup> Assuming that uncontrolled levels in Ontario brake plants could be as high as 10 f/cc, then the reduction of exposure from 10 to 1 f/cc would cost \$454 per operator per year per f/cc. In the case of the data presented in Table 6.8, reducing the control limit from 2 to 1 f/cc (1 to 0.5 f/cc exposure) costs \$1,349 per worker per year for a reduction of 0.5 f/cc, for a marginal cost of \$2,700 per year per operator per fibre. Reducing the control limit from 1 to 0.5 f/cc (0.5 to 0.25 f/cc exposure) costs \$2,522 per year per operator. Dividing this by the reduction in fibre level of 0.25 fibres yields a cost per year per operator per fibre of \$10,088. Similarly, reducing the control limit from 0.5 to 0.2 f/cc (0.25 to 0.1 f/cc exposure) costs \$78,447 per year per operator per f/cc. Figure 6.1 graphs the marginal cost of moving fibre control to the various levels just discussed. While the calculations have produced just four data points, we have drawn a smooth curve through these points in Figure 6.1. This implies that fibre levels *between* those analyzed could be achieved at the marginal cost indicated by the figure. The band on either side of the figure represents the range of uncertainty surrounding these cost estimates.

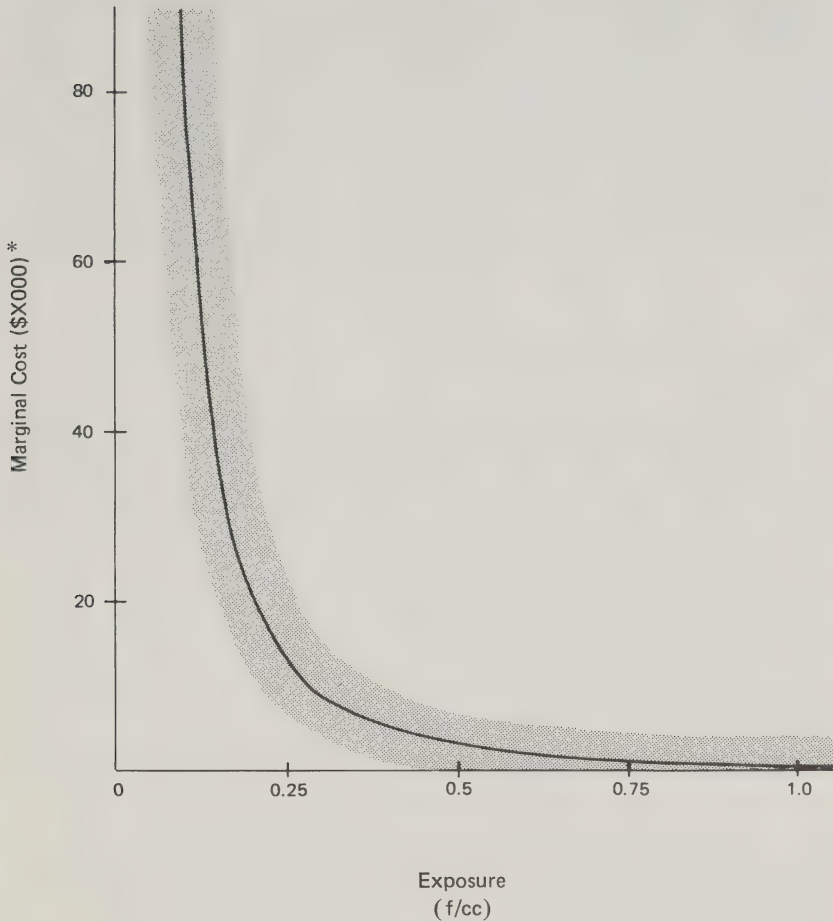
We conclude from this exercise and Figure 6.1 that the cost of controlling workplace exposure to asbestos may rise rapidly as control levels are reduced to and below the current Ontario control limit for chrysotile. Plausible control levels can yield costs of worker protection that are as great as the salary of the worker. Choices about control limits in this range can therefore substantially affect the cost of asbestos manufacturing in Ontario. We also conclude that while there are many sources of error and uncertainty in making such cost estimates, there is still substantial value in making them.

We now turn to another means of worker protection: the substitution of other materials for asbestos products.

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<sup>21</sup>Geoffrey Berry and Muriel L. Newhouse, "Mortality of Workers Manufacturing Friction Materials Using Asbestos," *British Journal of Industrial Medicine* 40:1 (February 1983): 1-7.

**Figure 6.1**  
**Marginal Cost of Fibre Control**  
**Hypothetical Brake Plant**



Data:	Control Limit (f/cc)	Exposure (f/cc)	Marginal Cost*
	2.0	1.0	454
	1.0	0.5	2,700
	0.5	0.25	10,088
	0.2	0.1	78,447

**Note:** \*Marginal total cost per year per operator per fibre of exposure.

## D. Feasibility and Cost of Substitutes for Asbestos

The exposure of manufacturing workers to asbestos can be eliminated by replacing asbestos in the product with some other fibre, or by replacing the product with a non-fibrous product. Considerable work has been done particularly in the United States during the last few years to identify and develop substitutes for asbestos. This search has found a variety of materials that can substitute for asbestos in various applications, but no single material that is satisfactory for all of the varied uses of asbestos. Thus, an investigation of asbestos substitutes must be conducted separately for each product type. We will review briefly here the available information on substitutes for the major products manufactured in Ontario.

### D.1 Friction Products

Friction materials are used in brakes and clutches for automobiles, trucks, airplanes, railroads, and industrial machinery. In the past, asbestos has been a major component of the pads used in disc brakes and in the linings of drum brakes. Substitutes for asbestos must be able to withstand high temperatures, maintain strength and durability, provide uniform friction characteristics over a wide range of temperatures and under wet and dry conditions, and not cause unreasonable wear for the brake disc or drum. Substitute materials include semi-metallic friction materials, cermets (ceramic and metal mixtures), as well as glass fibres, steel wool, mineral wool, carbon fibres, aramid fibres, vermiculite, silicon nitride, and potassium titanate fibres. Jacko, Brunhofer, and Aldrich reported that semi-metallic materials have been used in disc brake pads for special applications for a number of years, and are now being introduced in automobiles.<sup>22</sup> In 1980, semi-metallic disc pads were used on the front brakes of approximately half of all new North American vehicles, and it is expected that this fraction will approach 100% by 1985. Semi-metallic disc pads are somewhat more expensive than asbestos pads, but their performance is sufficiently good that this cost disadvantage has not prevented widespread acceptance. The GCA Corporation, in a report drafted for the U.S.

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<sup>22</sup>Michael G. Jacko, Charles M. Brunhofer, and F. William Aldrich, "Non-Asbestos Friction Materials," in *Proceedings of the National Workshop on Substitutes for Asbestos*, Arlington, Virginia: 14-16 July 1980, EPA-560/3-80-001 (Washington, D.C.: U.S. Environmental Protection Agency, 1980), p. 9.

Environmental Protection Agency, stated that most commercial airliners have used cermet disc brake pads for decades.<sup>23</sup>

Until recently, all drum brake linings were still asbestos-based. In drum brakes, the semi-metallic materials are not appropriate, and research is focused upon the alternative fibres mentioned above. Some of these fibres are difficult to handle in processing because they are brittle or difficult to spread uniformly throughout the mixture of ingredients prior to forming. In general, they have shown less frictional stability, greater noise problems, and excessive wear on the brake drum. However, research is continuing, and in the summer of 1983 two manufacturers had introduced non-asbestos drum brake linings on a limited scale.<sup>24</sup>

The cost of alternate brake shoe materials is difficult to predict. Jacko, Brunhofer, and Aldrich reported that substitute fibres alone range in cost from slightly cheaper than asbestos to 99 times more expensive than asbestos.<sup>25</sup> They estimate that asbestos-free drum brake linings may cost 20 to 50% more than current linings, while asbestos-free disc pads may cost 20 to 100% more than current pads.<sup>26</sup> The GCA Corporation report anticipated similar cost increases, except that they predicted a cost increase for drum brake linings of 20 to 25% above the cost of current linings.<sup>27</sup>

Even if all new vehicles were manufactured with non-asbestos disc and drum brake linings, existing vehicles would continue in use for many years. It is generally believed that replacement parts for the existing vehicles will have to be of a composition similar to that of the original product in order to maintain adequate performance. Thus, there may be a continuing demand for asbestos-containing brake shoes for the replacement market for many years after asbestos-free linings are developed.

A survey of Ontario manufacturers conducted by Professor Bragg as part of his study for this Commission showed that some firms in the friction products industry intended to phase out asbestos within five to ten years, while others had no plan to phase out asbestos. It appears that one

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<sup>23</sup>GCA Corporation, "Asbestos Substitute Performance Analysis," draft revised final report prepared by Nancy Krusell and David Cogley for the U.S. Environmental Protection Agency, GCA-TR-81-32-G (Bedford, Mass.: GCA Corporation, February 1982), p. 312. The information from the GCA Corporation report is currently being incorporated by the U.S. Environmental Protection Agency into an updated report, tentatively titled "Regulatory Impact Analysis for Asbestos Product Bans," in press, 1983. See especially Appendix B. Telephone communication between Ms. Amy Moll, Office of Toxic Substances, U.S. Environmental Protection Agency and Royal Commission on Asbestos Staff, 13 September 1983.

<sup>24</sup>These manufacturers are Raybestos-Manhattan and the BBA Group.

<sup>25</sup>Jacko, Brunhofer, and Aldrich, "Non-Asbestos Friction Materials," p. 17.

<sup>26</sup>*Ibid.*, p. 24.

<sup>27</sup>GCA Corporation, "Asbestos Substitute Performance Analysis," p. 104.

firm has been given the responsibility for manufacturing all asbestos brake materials for the parent company in North America, so that production has been shifted from the U.S. plant to this Ontario plant.

## D.2 Floor Tiles

Asbestos has long been used in vinyl-asbestos floor tiles, because it gives durability, dimensional stability, moisture resistance, a smooth surface, and easy cleaning. In 1975, asbestos-containing products commanded a 91% share of the resilient floor market.<sup>28</sup> Some companies are testing alternate fibres to substitute for asbestos in floor tiles. This research is generally proprietary, so little is known about the characteristics of floorings containing these alternate fibres. There are also alternative products including solid vinyl tiles, rubber tiles, and linoleum. Each of these products is said to be inferior to vinyl-asbestos tile in some important respects such as grease resistance, stain resistance, or durability. The substitutes tend to be considerably more expensive than vinyl-asbestos floor tile, with price premiums of 10 to 50%.<sup>29</sup> Thus, at the present time, there are alternatives to vinyl-asbestos floor tile, but they do not have the cost and performance characteristics of the vinyl-asbestos product. One Ontario manufacturer has placed on the market an asbestos-free vinyl floor tile, and while its cost and market acceptance are not as yet known, there appears to be some demand for an asbestos-free product.

## D.3 Gaskets and Packings

Asbestos is used in gaskets and packings to provide heat resistance, resiliency, strength, and resistance to strong chemicals. A number of fibres have been tested to replace asbestos in gaskets and packings, including graphite, carbon, aramid, cermet, silica, and Teflon fibres. Some non-fibrous gasket materials also exist. Aramid fibres are strong and low cost, providing a long surface life, but are hard to cut and have a 500°F temperature limit. Graphite/TFE compositions are also attractive for packing, withstanding a wide range of acid or alkali conditions, with a number of attractive characteristics, particularly for packing chemical pumps. Carbon fibre is expensive, but can withstand high shaft speeds and high temperatures. In the gasket product, a variety of fibre and non-fibre alternatives exist, which when combined cover virtually the entire range of asbestos product applications.

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<sup>28</sup>Ibid., p. 173.

<sup>29</sup>Ibid., p. 179.

The GCA Corporation report concluded that "New packing materials appear to be more than viable alternatives [to asbestos], offering less abrasion and thus lower operating and maintenance costs. It appears that only sales and engineering resistance stand in the way of a total switchover to non-asbestos packings."<sup>30</sup> The U.S. Environmental Protection Agency's *Proceedings of the National Workshop on Substitutes for Asbestos* also appeared to conclude that the variety of asbestos substitutes left few if any users locked into asbestos products for gaskets and packings. The cost penalty for a non-asbestos product is thought to be negligible except in high temperature applications. However, Pye has noted that asbestos can cover a wide range of uses, while a variety of substitutes might be needed to cover the same range.<sup>31</sup> Thus, the continued use of asbestos gaskets and packings can help to minimize inventory problems.

#### D.4 Paints, Sealants, and Coatings

Asbestos is used in paints, sealants, and coatings such as automotive undercoating and asphalt roofing compounds, because it absorbs sound, is waterproof, adds strength, reduces flow or sag of the coating, and is durable, economical, and resistant to corrosion and heat. Asbestos mixes and binds well with petroleum products and particularly asphalt. Alternative substitute fibres do not in general have this affinity for asphalt, which give them less satisfactory performance. Thus, a number of asbestos-free substitutes are available, but they tend to be more expensive and less durable or otherwise less satisfactory than asbestos-containing coatings. Brzozowski reported that the cost of asbestos substitutes for roof coatings are from 2 to 20 times greater than the cost of the asbestos itself, which means that the finished product is 10 to 150% more expensive than the asbestos-containing product.<sup>32</sup> The non-asbestos fibres that have been used in roof coatings are generally not inert, so that over time they degrade or settle or are attacked by chemicals. Thus, the asbestos-free products provide lower durability and performance than the asbestos-containing products.

Textured paint, spackling, and drywall joint compounds used to contain asbestos, but now are generally asbestos-free. For non-asphalt coatings, a wide variety of asbestos substitutes have been used including talc, silica, clay, and mica. For pipe coatings, there are a number of asbestos-free alternatives including enamels, plastics, phenolic tapes and wax coatings, poly-

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<sup>30</sup>Ibid., p. 314.

<sup>31</sup>Andrew M. Pye, "The Feasibility of Substitution," in *Proceedings of the World Symposium on Asbestos*, Montreal, Quebec: 25-27 May 1982 (Montreal, P.Q.: Canadian Asbestos Information Centre [1983]), p. 216.

<sup>32</sup>Kenneth Brzozowski, "Asbestos Substitutes in Roof Coatings," in *Proceedings of the National Workshop on Substitutes for Asbestos*, p. 109.

urethane foam insulation, and concrete. The problems with these substitutes are substantially less than with the asphalt products. Ontario manufacturers of paints, sealants, and coatings indicated that some had abandoned asbestos use, while others were investigating asbestos substitutes.

## D.5 Plastics

Asbestos has been used as a filler to provide strength in phenolic molding compounds and other plastic products. Here asbestos provides a filler and reinforces the plastic, giving it strength, resistance to heat and fire, and less shrinkage and warping than other fibres. A variety of asbestos substitutes are available for this use including clay, talc, wollastonite, glass fibres and processed mineral fibres. The GCA Corporation report concluded that most of these substitutes are economically competitive with asbestos and yield satisfactory product qualities.<sup>33</sup> Some of the substitutes, however, cost many times as much as asbestos fibres, and the resulting product is more costly to process.<sup>34</sup> There has been a move from asbestos to these substitutes in recent years, a trend which is expected to continue, leaving asbestos only in some specialty products. An Ontario manufacturer of reinforced plastics, however, reported that it felt non-asbestos substitute products to be inferior and had no plans to phase out asbestos within the next decade.

## D.6 Asbestos-Cement Pipes and Sheets

At present there is no manufacturer of asbestos-cement pipe in Ontario, but the Johns-Manville plant in Scarborough was the major asbestos user in the province from the late 1940s until 1980. Asbestos-cement pipe has been used for sewer pipe and for water supply piping. The asbestos reinforces the cement mixture, giving strength to the pipe, as well as providing resistance to corrosive soils. Several alternative fibres are under consideration for pipe manufacture, including fibreglass, while iron pipe and plastic pipe are competing products for water supply, and clay pipe and concrete pipe are competing products for sewage and drainage pipes. Thus, it appears for most applications that at least one alternative to asbestos-cement pipe will offer satisfactory performance, and the main factor of choice is economics. Asbestos-cement pipe may cost 25% less than ductile iron pipe for diameters up to 12 inches, and it is easier to tap.<sup>35</sup> It appears that for small pressure pipes, plastic has a competitive edge over asbestos, in part because it is light-weight and requires less field labour to

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<sup>33</sup>GCA Corporation, "Asbestos Substitute Performance Analysis," p. 315.

<sup>34</sup>*Ibid.*, pp. 258-259.

<sup>35</sup>*Ibid.*, pp. 142-143.

install. The GCA Corporation report concluded that asbestos-cement pipe is still most suitable for diameters of 6 to 24 inches, although others have suggested that plastic pipe is highly competitive over some of this size range.<sup>36</sup>

Bragg reported that very little asbestos-cement pipe seems to be installed in Ontario today. He concluded that the major Canadian market for this pipe is in the western provinces, with plastic and other types of pipe having taken over most of the eastern market.<sup>37</sup>

## E. Health Effects of Substitutes for Asbestos

The preceding section identified competitive materials which could serve as substitutes for asbestos in various product applications. However, in addition to performance and economic criteria, one must incorporate consideration of the health effects of alternative materials into the evaluation of substitutes. It would be unfortunate if asbestos were replaced with a substance characterized by greater carcinogenic or fibrogenic properties.

Many problems complicate the appraisal of the health consequences of alternative materials, including: (i) diversity and definition of asbestos substitutes; (ii) the incomplete understanding of the toxicology and pharmacokinetics of fibre particulates; (iii) the limited development of scientific criteria for determining toxicities due to factors (i) and (ii); and (iv) the uncertainty involved in the assessment of quantitative risks to humans by extrapolation from toxicological data in other species.<sup>38</sup>

Here we will summarize the results of epidemiological and animal studies purporting to assess the health effects of substitute materials for asbestos. The available substitutes for asbestos are classified into three broad categories: synthetic fibre substitutes; natural fibre substitutes; and natural non-fibre substitutes.

### E.1 Synthetic Fibre Substitutes

Man-made vitreous fibres (MMV) such as fibrous glass, rock and slag wool, and ceramic fibre may be used as substitutes for asbestos in various insulation applications. Fowler has reported that production workers exposed to man-made vitreous fibres generally experience relatively low

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<sup>36</sup>Ibid., p. 313.

<sup>37</sup>Bragg, *The Technical Feasibility and Cost of Controlling Workplace Exposure to Asbestos Fibres*, p. 85.

<sup>38</sup>James N. Rowe, "Scope of the Health Workshop," in *Proceedings of the National Workshop on Substitutes for Asbestos*, p. 279.

exposures to the material (less than 1 f/cc), while user workers have more variable exposure.<sup>39</sup>

Konzen, after surveying the available medical literature on man-made vitreous fibres, concluded that in man “. . . there is no credible evidence of malignant or chronic progressive non-malignant disease resulting from exposure to man-made vitreous fibers.” In laboratory animals, disease was produced only “. . . when fibers were administered by an artificial route which bypassed physiologic defenses.”<sup>40</sup> And, although a recently completed epidemiological study by Robinson et al. detected increased mortality related to gastrointestinal cancer and non-malignant respiratory disease in workers previously employed in a rock and slag wool factory, the excess was not considered statistically significant at the 95% confidence level.<sup>41</sup> As of 1980, when Konzen and Robinson reported, this leaves some possibility of adverse health effects, but not *proven* health effects.

Recently, Enterline, Marsh, and Esmen studied the health of workers exposed to fibreglass and mineral wool.<sup>42</sup> After 20 years from first exposure, they found standard mortality ratios (SMRs) for respiratory cancer of 108 among the fibreglass workers and 157 among the mineral wool workers. The estimated exposure to respirable dust was 0.5 f/cc for fibreglass and 5 f/cc for mineral wool, the former being a very low exposure level. While the fibreglass disease rate was very low, so was the exposure. If one develops a dose-response relationship from the data contained in this study, the cancer risk per f/cc of exposure is in fact relatively high. Finkelstein concluded that these data imply an increase in relative risk of 16% per f/cc-yr and 12% per f/cc-yr for fibreglass and mineral wool exposure respectively.<sup>43</sup> These risks are twice as great as the cancer risks from asbestos exposure found at the Johns-Manville plant in Scarborough. This study suggested that the failure to detect high disease levels among fibreglass or mineral wool workers may arise from the low concentrations of respirable dust to which they were exposed. If changes in the manufacturing processes for these materials were to lead to airborne concentrations of respirable fibres substantially above the low historical levels, serious

<sup>39</sup>Douglas P. Fowler, “Occupational Exposure to Mineral Wool,” in *Proceedings of the National Workshop on Substitutes for Asbestos*, p. 412.

<sup>40</sup>Jon L. Konzen, “Man-Made Vitreous Fibers and Health,” in *Proceedings of the National Workshop on Substitutes for Asbestos*, pp. 329, 332.

<sup>41</sup>Cynthia F. Robinson et al., “Mortality Patterns of Rock and Slag Mineral Wool Production Workers: Epidemiologic and Environmental Study,” in *Proceedings of the National Workshop on Substitutes for Asbestos*, p. 419.

<sup>42</sup>Philip E. Enterline, Gary M. Marsh, and Nurtan A. Esmen, “Respiratory Disease Among Workers Exposed to Man-Made Mineral Fibers,” *American Review of Respiratory Disease* 128:1 (July 1983): 1-7.

<sup>43</sup>Murray M. Finkelstein, “Mortality Among Employees of an Ontario Asbestos-Cement Factory,” Toronto, Ontario Ministry of Labour, February 1983, revised September 1983, p. 20. (Mimeographed.)

disease might result. Specifically, risks might increase if there were a reduction in the diameter of fibres of these types that are produced, and thus to which workers are exposed. A 1977 criteria document by the U.S. National Institute for Occupational Safety and Health (NIOSH) recommended that worker exposure to fibreglass in the United States be limited to 3 f/cc of fibres thinner than 3.5 microns and longer than 10 microns.<sup>44</sup>

## E.2 Natural Fibre Substitutes

Boehlecke et al. completed a clinical examination of 104 workers in a wollastonite (a fibrous mono-calcium silicate) plant in the United States and found that 23% of the smokers and ex-smokers and 9% of the non-smokers suffered from chronic bronchitis. However, there was no association between prevalence of bronchitis and increases in exposure to the material. The researchers concluded by cautioning that "Because only 36% of men studied had over 15 years' exposure, further follow-up is needed to determine if wollastonite is truly less hazardous than asbestos."<sup>45</sup>

Rohl has investigated the high mesothelioma mortality in an agricultural region in Turkey.<sup>46</sup> Rohl was unable to detect any evidence of asbestos in the area, and postulated that the carcinogen responsible for inducing the disease was zeolite, a fibrous substance having similar dimensions to some asbestos fibres. This supposition was consistent with the results of animal studies undertaken by Wagner which found that all animals inoculated with zeolite and surviving one week after the procedure eventually developed mesothelioma.<sup>47</sup>

Flowers has proposed that it may be possible to reduce the toxic potency of asbestos fibres while retaining the desirable attributes of the material. This is accomplished by attaching ferric oxides to the fibres.<sup>48</sup> Initial results from *in vivo* testing indicated a reduction in the cytotoxicity of these treated forms of asbestos. However, biological activity was measured from only 72 hours after treatment, so further investigation is needed on the carcinogenic and fibrogenic potential of these treated substances

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<sup>44</sup>U.S., Department of Health, Education and Welfare, National Institute for Occupational Safety and Health, *NIOSH Criteria for a Recommended Standard . . . Occupational Exposure to Fibrous Glass* (Washington, D.C.: U.S. Government Printing Office, April 1977), p. 7.

<sup>45</sup>Brian Boehlecke et al., "Cross-Sectional Medical Study of Wollastonite Workers," in *Proceedings of the National Workshop on Substitutes for Asbestos*, p. 475.

<sup>46</sup>Arthur N. Rohl, "Endemic Pleural Disease in Relation to Zeolite Exposure," in *Proceedings of the National Workshop on Substitutes for Asbestos*, p. 477.

<sup>47</sup>J. Christopher Wagner, "Health Hazards of Substitutes," in *Proceedings of the World Symposium on Asbestos*, pp. 249-251, 263-265.

<sup>48</sup>Earl S. Flowers, "Chemical Detoxification of Asbestos Fibers," in *Proceedings of the National Workshop on Substitutes for Asbestos*, p. 489.

before their relative health effects can be conclusively determined. In testimony before this Commission, Dr. Jacques Dunnigan described the experimental treatment of asbestos fibres with heat, acid, and other compounds, especially phosphate, all designed to reduce the health risk from asbestos fibres while retaining the desirable properties of the fibres.<sup>49</sup> Concomitantly, there has been research on the adverse health effects of these modified fibres. While it is too early to judge the economic feasibility of these treatments, or the reduction they may achieve in health effects, it is possible that in the future a treated asbestos will emerge as a safer substitute for untreated asbestos.

### E.3 Natural Non-Fibre Substitutes

Talc has been suggested as a substitute for asbestos in some applications. Assessing the health effects of talc is difficult because the mineral is frequently contaminated with other substances, sometimes asbestos. Studies of miners and millers exposed to talc contaminated with amphibole asbestos found some excess in respiratory cancer as well as other respiratory disease.<sup>50</sup> Gamble et al. attempted to correct for the problem of talc contaminated with other minerals with proven fibrogenic and carcinogenic properties by examining workers from three different talc mines in the United States.<sup>51</sup> Each mine was characterized by varying grades of talc purity. The researchers found that there was neither an increase in symptoms of pneumoconiosis nor biologically significant reductions in lung functions among workers from the three mines examined. Yet the amount of bilateral pleural thickening in talc workers was significantly elevated over the levels found in a comparison population not exposed to the mineral.

It has been reported that exposure to other natural non-fibrous substitutes for asbestos such as mica and vermiculite can cause increased prevalence of pulmonary abnormalities in employees processing these materials.<sup>52</sup>

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<sup>49</sup>Ontario, Royal Commission on Asbestos, Transcript of Public Hearings [hereafter RCA Transcript], Evidence of Dr. Jacques Dunnigan, 20 August 1981, Volume no. 28, p. 7.

<sup>50</sup>David P. Brown, John M. Dement, and Joseph K. Wagoner, "Mortality Patterns Among Miners and Millers Occupationally Exposed to Asbestiform Talc," in *Dusts and Disease*, eds. Richard A. Lemen and John M. Dement (Park Forest South, Illinois: Pathatox Publishers Inc., 1979), p. 317; Morris Kleinfeld et al., "Mortality Among Talc Miners and Millers in New York State," *Archives of Environmental Health* 14 (1967): 663; and Morris Kleinfeld, Jacqueline Messite, and Mahfouz H. Zaki, "Mortality Experiences Among Talc Workers: A Follow-up Study," *Journal of Occupational Medicine* 16 (1974): 345.

<sup>51</sup>John Gamble, Alice Greife, and John Hancock, "Cross-Sectional Epidemiologic and Industrial Hygiene Survey of Talc Workers Mining Ore from Montana, Texas, and North Carolina," in *Proceedings of the National Workshop on Substitutes for Asbestos*, p. 570.

<sup>52</sup>James Lockey and Stuart M. Brooks, "Health Effects of Vermiculite," in *Proceedings of the National Workshop on Substitutes for Asbestos*, p. 555.

## E.4 Assessment

We conclude from this evidence that the widely discussed substitutes for asbestos have not in general been proved to be carcinogenic or toxic. However, most of these substitutes have been used in ways that have not created airborne concentrations of respirable fibres comparable to the asbestos fibre levels of twenty or more years ago. It may be that they are not as hazardous, fibre for fibre, as asbestos has proved to be. However, the evidence does not rule out the likelihood that some of these materials will ultimately be determined to cause cancer or respiratory disease if substantial quantities are inhaled. There are few cases where a substitute is available that has been "proved safe," in part because such proof is very difficult to establish.

In Chapter 5 we conclude that the health hazards caused by exposure to asbestos fibres depend very much upon the dimensions of the fibres, and that long, thin, respirable fibres are of primary concern. This leads us to be extremely cautious about concluding from the evidence discussed above that substitute fibres will not present health hazards in the future. If the production of substitute fibres in the future should increase the exposure of workers to long, thin, durable fibres of dimensions similar to those we have found hazardous for asbestos, we cannot be sure that serious health consequences would not result. In the face of the existing evidence, we believe it would be risky to allow the exposure of workers to respirable fibres longer than 5 microns, with small diameters, of any material, if those fibres are likely to be very durable in the lungs.

## F. Mining and Milling in Ontario

Mining of asbestos in Ontario has never contributed substantially to total Canadian output of asbestos and has not been a major component of the Ontario mining industry. Four mines have produced asbestos in Ontario in the recent past. The Munro Mine outside Timmins, Ontario, closed in 1968. No production figures are available, but the Ontario Federation of Labour (OFL) estimated that the total workforce over the life of this mine included 2,000 workers.<sup>53</sup> The Reeves Mine, also near Timmins, was owned by Johns-Manville Canada and closed in early 1975. The Ontario Federation of Labour estimated that this mine employed between 800 and 1,000 workers during its operating life.<sup>54</sup> The OFL stated that between 1969 and 1975, the fibre counts in the Reeves Mine rose from around 2 f/cc in the early months of 1969 to average between 7 and 10 f/cc in 1970. In August

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<sup>53</sup>Ontario Federation of Labour, Written submission to the Royal Commission on Asbestos, #35, January 1981, p. 48.

<sup>54</sup>Ibid.

1972, 4 out of 15 dust counts exceeded 5 f/cc, with a maximum of 22 f/cc. In 1974, the average of all readings is alleged to have been 14.7 f/cc, with individual readings many times this level, and 34 of 54 sampling stations above 5 f/cc. The mine was closed when Johns-Manville concluded that it could not economically meet a 2 f/cc time-weighted average (TWA) exposure limit. The ore body was estimated to have a three-year supply remaining.

The Matachewan Mine in Midlothian Township outside of Kirkland Lake operated between 1975 and 1977, employing a total workforce over this period of approximately 500 workers according to the Ontario Federation of Labour.<sup>55</sup> This mine was owned by United Asbestos, and was the only Ontario asbestos mine identified by Vagt.<sup>56</sup> He stated that the mill had a capacity of 3,600 tons per day of ore and an annual capacity of 100,000 tons of fibre. During the short operating life of this mine, continual problems occurred in trying to achieve the 2 f/cc TWA exposure limit.

The principal mine that has recently operated in Ontario is the Hedman Mine near Matheson, which was not listed by Vagt as an asbestos producer. The mill, located in the town of Matheson, has a capacity of 300 tons per day of ore. The mine and mill employ under 20 workers. The product contains about 20% chrysotile fibre. Another mine near Sharbot Lake currently produces a non-asbestiform tremolite.<sup>57</sup> The Ontario Ministry of Natural Resources recently completed a study reviewing asbestos deposits in the Kirkland Lake - Timmins area, concluding that the potential for commercial deposits of asbestos and talc is good.<sup>58</sup>

Asbestos exposure might also occur in other mines where asbestos fibres are present in the rock. A talc mine operated by Canadian Talc Limited, near Madoc, has shown some asbestos fibre exposure in Ministry of Labour inspections. The Ministry of Labour conducted its air sampling at the rock crushers of three nickel mines in 1981 and found asbestos fibre levels predominantly below 0.1 f/cc with a maximum of 0.22 f/cc.<sup>59</sup>

Table 6.11 shows asbestos fibre exposures in Ontario asbestos and talc mines since 1975. The table shows high exposures occurring in the

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<sup>55</sup>Ibid., p. 49.

<sup>56</sup>Vagt, *Asbestos*, p. 6.

<sup>57</sup>Letter from Mr. Dennis Yakota, Ram Petroleum Limited to the Royal Commission on Asbestos, 15 April 1983.

<sup>58</sup>Ulrich Kretschmar and Dianne Kretschmar, *Talc, Magnesite, and Asbestos Deposits in the Kirkland Lake - Timmins Area, Districts of Timiskaming and Cochrane*, Ontario Geological Survey Open File Report 5391 (Toronto: Ontario Ministry of Natural Resources, 1982), p. 125.

<sup>59</sup>Letter from Mr. Hugh M. Nelson, Special Assistant, Industrial Hygiene, Occupational Health and Safety Division, Ontario Ministry of Labour to the Royal Commission on Asbestos, 14 September 1981.

mid-1970s while average exposures by 1980 were generally within the 2 f/cc guideline.

Bragg noted that in open-pit mining, workers may be protected from fibre levels in excess of 2 f/cc by enclosing the work stations on the equipment that they operate.<sup>60</sup> He concluded that “. . . with the exception of blasting crews, enclosures costing approximately \$5,000 to \$10,000 per operating station would provide fibre levels at 0.1 f/cc except while entering and leaving the working area. It is expected that blasters would have to wear personal protective devices in the presence of high fibre levels.” In the milling operation, it is unlikely that fibre levels can be reliably reduced below 2 f/cc. Even this level would require careful maintenance. Bragg concluded that “It is our estimation that only personal protective devices could provide fibre levels below 2 f/cc for personnel in present asbestos mills.”<sup>61</sup> While wet-milling processes have been developed and are used elsewhere in the world, water may render the fibre unfit for the uses to which Canadian fibre is usually put. Research is ongoing in Australia trying to find ways to make this process compatible with the major uses of chrysotile asbestos.

## G. Other Fixed Place Exposure

In addition to mining and manufacturing, Ontario fixed place workers may be exposed to asbestos in brake repair, in shipbuilding and repair, and in railroad equipment maintenance. The exposures that occur in these activities will be reviewed below.

### G.1 Asbestos Exposure During Brake Repair

Chrysotile asbestos is widely used as a major component of automotive brakes, in both disc pads and drum linings. Depending on the type of brake, the asbestos content of the pad or lining will constitute from 25 to 65% of the total product weight. Within the last few years, cost- and performance-competitive non-asbestos substitutes have become available for disc brakes. However, while some of the major brake manufacturers have recently begun to market non-asbestos drum brake linings, they are available only in a limited number of applications. This suggests that we cannot, in the immediate future, rely on the substitution of non-asbestos materials for asbestos in brakes as the sole method of controlling the asbestos exposure received by brake mechanics, but instead must assume that many brakes will continue to contain asbestos.

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<sup>60</sup>Bragg, *The Technical Feasibility and Cost of Controlling Workplace Exposure to Asbestos Fibres*, pp. 84-85.

<sup>61</sup>Ibid., p. 85.

**Table 6.11**  
**Summary of Asbestos Dust Levels in Ontario Asbestos and Talc Mines**  
**(Fibres per Cubic Centimetre)**

<b>Year</b>		<b>Average</b>	<b>Range</b>	<b>% Greater than 2 f/cc</b>
1975	Area	1.4	to 2.4	18
	Personal	3.8	to 10.1	60
1976	Area	2.9	to 45.0	37
	Personal	3.2	to 13.4	63
1977	Area	3.3	to 10.3	58
	Personal	4.9	to 16.2	83
1978	Area	1.3	to 7.2	12
	Personal	2.0	to 6.2	46
1979	Area	0.8	to 1.0	0
	Personal	2.4	to 6.3	NA
1980	Area	2.3	to 6.5	63
	Personal	1.5	to 9.2	14

SOURCE: Ontario Ministry of Labour data.

Automotive mechanics may be exposed to brake dust during inspection, modification, removal, or installation of brake linings. However, the extent of occupational exposure to asbestos in the servicing of disc brakes is considerably less than in the servicing of drum brakes because disc brakes retain little brake wear debris and disc pads seldom require manual modification to ensure a good fit. During the inspection and installation of drum brake linings, the exposure to asbestos may result from the removal of brake wear debris from the drum and back plates. Historically, brake wear debris was most frequently removed by directing compressed air into the brake housing, to blow out the debris deposited in the drum.<sup>62</sup>

A substantial body of scientific literature has reported that the asbestos undergoes significant chemical and physical alteration during braking. While it is generally agreed that the high temperature experienced during braking alters the asbestos, there is still debate surrounding both the extent of this alteration and the identity and characteristics of the wear debris that is produced. For example, Jacko and DuCharme suggested that the high temperature experienced during vehicle braking caused 99.7% of the asbestos in the brake linings to be converted into inert, harmless particles.<sup>63</sup> Similar results were reported by Lynch; Hatch; Hickish and Knight; Anderson et al.; and Williams and Muhlbaier.<sup>64</sup> And, while Alste, Watson, and Bagg concluded that the major effect of braking appears to be the separation of bundles of fibres and reduction of average length without any crystal structure alteration,<sup>65</sup> Jacko has suggested that the wear debris collected by Alste, Watson, and Bagg may have resulted from studying brake linings with poor wear characteristics.<sup>66</sup>

Williams and Muhlbaier conducted 23 analyses of wear products from disc brakes and 24 from drum brakes.<sup>67</sup> They found that the average

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<sup>62</sup>Barry Castleman et al., "The Hazards of Asbestos for Brake Mechanics," *Public Health Reports* 90:3 (May-June 1975): 254-256.

<sup>63</sup>Michael G. Jacko and Robert T. DuCharme, "Brake Emissions: Emission Measurements from Brake and Clutch Linings from Selected Mobile Sources," EPA Report 68-04-0020, NTIS PB-222-372 (Southfield, Michigan: Bendix Research Labs, March 1973).

<sup>64</sup>Jeremiah R. Lynch, "Brake Lining Decomposition Products," *Journal of the Air Pollution Control Association* 18 (1968): 824-826; D. Hatch, "Possible Alternatives to Asbestos as a Friction Material," *Annals of Occupational Hygiene* 13:1 (January 1970): 25-29; D.E. Hickish and K.L. Knight, "Exposure to Asbestos During Brake Maintenance," *Annals of Occupational Hygiene* 13:1 (January 1970): 17-21; A.E. Anderson et al., "Asbestos Emissions from Brake Dynamometer Tests," SAE Paper 730549 presented at Society of Automotive Engineers Meeting, Detroit, Michigan, 14-16 May 1973; and Ronald L. Williams and Jean L. Muhlbaier, "Asbestos Brake Emissions," *Environmental Research* 29 (1982): 70-82.

<sup>65</sup>J. Alste, D. Watson, and J. Bagg, "Airborne Asbestos in the Vicinity of a Freeway," *Atmospheric Environment* 10:8 (1976): 583-589.

<sup>66</sup>Michael G. Jacko, "Physical and Chemical Changes of Organic Disc Pads in Service," *Wear* 46 (1978): 163.

<sup>67</sup>See note 64, *supra*.

asbestos content of the wear products was 0.029%, which means that over 99.9% of the asbestos in the brake pad or shoe was transformed chemically or physically so that it was no longer an identifiable asbestos fibre. Furthermore, they found that less than 1% of all asbestos fibres observed were longer than 5 microns.

Rohl et al. analyzed the wear debris from brake drums of automobiles and found that in general only 3 to 6% by weight of the debris was recognizable asbestos, implying that 94 to 97% of the debris was some other material.<sup>68</sup> They further determined that such asbestos as was present in the wear debris consisted predominantly of short fibres. About 80% of the asbestos fibre in the debris was shorter than 3,750 Angstroms (0.375 microns) in length<sup>69</sup> so that a very small fraction, perhaps 1%, of these fibres would have been longer than 5 microns. Thus, researchers seem to be in agreement that brake wear produces debris that is 6% or less asbestos, and that less than 1% of these asbestos fibres are longer than 5 microns.

Fibre levels experienced during removal of brake wear debris and reported by various authors are summarized in Table 6.12. Most of the readings were derived from optical measurements which means that non-asbestos fibres as well as asbestos fibres were counted. Although the peak levels reported in a number of studies were high (87 f/cc), these levels were realized only intermittently and for brief durations. In contrast, the samples taken over a longer period that included these peak exposures, yielded time-weighted average fibre counts within the range of values found in other occupational exposures to asbestos in Ontario. Furthermore, since we concluded that asbestos constitutes a small fraction of the brake wear debris, it is likely that many of the reported airborne fibres were not asbestos fibres, and that the actual concentrations of asbestos fibres longer than 5 microns experienced during removal of wear debris were below the current 1 f/cc control limit, on a time-weighted average basis.

Table 6.12 also shows airborne fibre levels experienced during modification of new brake linings. Grinding and bevelling new brake linings to allow them to fit the brake drum do not subject the lining to the same high temperatures that are experienced during braking, so physical and chemical alteration of asbestos is unlikely to occur. Thus, the exposure of mechanics during grinding of brake linings resembles more closely the exposure experience of employees engaged in friction products manufacture than it does the exposure of mechanics involved in removing brake wear debris from drums, in that most fibres observed during grinding will be asbestos fibres.

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<sup>68</sup>Arthur N. Rohl et al., "Asbestos Exposure During Brake Lining Maintenance and Repair," *Environmental Research* 12 (1976): 113.

<sup>69</sup>Ibid., Table 2, p. 117.

Table 6.12 shows that bevelling and grinding may cause considerable fibre release. For instance, Lorimer et al. reported dust levels gathered during personal samplings of short duration, analyzed by optical microscope, which ranged from 1.7 to 7.0 f/cc for grinding truck brake linings and 23.7 to 72.0 f/cc for bevelling new linings.<sup>70</sup> The Ontario Ministry of Labour found fibre levels ranging from less than 0.1 f/cc to 15.6 f/cc during machining of brake linings at five brake relining shops in Ontario.<sup>71</sup>

Considering the fibre levels reported in these activities, we believe that the mechanics who regularly grind and bevel brake linings without undertaking proper precautions may be exposed to airborne asbestos fibre concentrations that exceed either the current Ontario chrysotile short-term exposure limit or the TWA control limit, or both.

Medical studies investigating the relationship between brake repair and the incidence of pulmonary disease have consistently demonstrated a greater prevalence of abnormalities among brake repair workers than would be expected in the general population.<sup>72</sup> As well, Newhouse and Thompson, Greenberg and Davies, and A.D. McDonald et al. have all documented cases of mesothelioma in brake repair and automotive mechanics.<sup>73</sup> While it has been suggested that the pattern of disease manifested in brake repair workers parallels that of workers employed in industries with occupational exposure to asbestos, no epidemiological investigation of mortality has been conducted which would either support or refute this proposition.

There are three distinct types of brake repair facilities in Ontario. The first type encompasses the vast majority of the estimated 11,000 establishments in Ontario doing automotive work. Most of these shops are general service stations, independent garages, and franchised new car dealers that will rarely perform more than 8 to 10 brake jobs per week. None of the

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<sup>70</sup>William V. Lorimer et al., "Asbestos Exposure of Brake Repair Workers in the United States," *The Mount Sinai Journal of Medicine* 43:3 (May-June 1976): 207-218.

<sup>71</sup>Letter from Mr. Arthur L. Gladstone, Senior Policy Advisor, Occupational Health and Safety Division, Ontario Ministry of Labour to the Royal Commission on Asbestos, 12 August 1981.

<sup>72</sup>See, for example, M.A. Boillat and M. Lob, "Risk of Asbestosis in Workers Employed in Replacing Automobile Brake Linings," *Schweizerische Medizinische Wochenschrift* 103:39 (1973): 1354-1359; Lorimer et al., "Asbestos Exposure of Brake Repair Workers in the United States," and William J. Nicholson, "Investigation of Health Hazards in Brake Lining Repair and Maintenance Workers Occupationally Exposed to Asbestos," final report to the U.S. National Institute for Occupational Safety and Health, April 1983. (Mimeographed.)

<sup>73</sup>Muriel L. Newhouse and Hilda Thompson, "Mesothelioma of Pleura and Peritoneum Following Exposure to Asbestos in the London Area," *British Journal of Industrial Medicine* 22 (1965): 261-269; Morris Greenberg and T.A. Lloyd Davies, "Mesothelioma Register 1967-68," *British Journal of Industrial Medicine* 31 (1974): 91-104; Alison D. McDonald et al., "Epidemiology of Primary Malignant Mesothelial Tumors in Canada," *Cancer* 26:4 (1970): 914-919.

Table 6.12  
Asbestos Exposure During Brake Maintenance

Reference	Operation	Sampling Method/Location (Number)	Sample Period (Minutes)	Fibre Concentration (f/cc)	Peak/ TWA*	Comments
Hickish and Knight <sup>a</sup>	Blowing out dust	Area by side of car (2)	90	1.25	TWA	Four brake blowouts during time
	Brake cleaning on trucks	Area on dust cloud during blowing (2)	90	2.55	TWA	
		Personal (2 men)	450	0.68	TWA	— eight hour shift
			100	7.09	TWA	— brake work
			300	0.08	TWA	— not working on brakes
Knight and Hickish <sup>b</sup>	Background	Area (AM/PM)				
	— adjacent bay		180	0.28/0.07	TWA	Brakes blown
	— 2 bays away		180	0.17/0.07	TWA	in AM but
	— garage centre		180	0.49/0.11	TWA	not in PM
Knight and Hickish <sup>b</sup>	Blowing dust	Personal	60	5.35		
			60	0.84		
		Personal (2)	2 secs.	87.0	Peak	During blowing
		Area samples adjacent bay	60	0.52		
			60	0.16		
Hatch <sup>c</sup>	Blowing dust	Area samples in dust cloud (7)	few secs.	43 ± 2.1	Peak	Hand-held pump
Lorimer et al. <sup>d</sup>	Blowing dust	Personal 3-5 ft. from operation (4)	2-10	6.6-29.4	Peak	
		Personal 5-10 ft. from operation (3)	2-10	2.0- 4.2	Peak	
		Personal 10-20 ft. from operation (2)	2-10	0.4- 4.8	Peak	
		Background 10-75 ft. from operation (6)	few secs. - 10 mins.	0.1- 0.8	Peak	
	Grinding used truck brakes	Personal (10)	2-10	1.7- 7.0		
	Beveling new linings	Background 10-60 ft. (5)		0.2- 1.7		
		Personal (5)		23.7-72.0		
		Background 8-30 ft. (4)		0.3- 0.6		

Table 6.12 (continued)  
Asbestos Exposure During Brake Maintenance

Reference	Operation	Sampling Method/Location (Number)	Sample Period (Minutes)	Fibre Concentration (f/cc)	Peak/ TWA*	Comments
Rohl et al. <sup>e</sup>	Cleaning drums with dry brush	1-3 ft. from operation (2)	3-8	1.3- 3.6	Peak	
	Background samples 3 minutes after cleaning drums with dry brush	12 ft. (3)		0- 0.2		

**Note:** \* TWA means time-weighted average.

**SOURCE:** <sup>a</sup>D.E. Hickish and K.L. Knight, "Exposure to Asbestos During Brake Maintenance," *Annals of Occupational Hygiene* 13:1 (January 1970): 17-21.  
<sup>b</sup>K.L. Knight and D.E. Hickish, "Investigations into Alternative Forms of Control for Dust Generated During the Cleaning of Brake Assemblies and Drums," *Annals of Occupational Hygiene* 13:1 (January 1970): 37-39.  
<sup>c</sup>D. Hatch, "Possible Alternatives to Asbestos as a Friction Material," *Annals of Occupational Hygiene* 13:1 (January 1970): 25-29.  
<sup>d</sup>William V. Lorimer et al., "Asbestos Exposure of Brake Repair Workers in the United States," *The Mount Sinai Journal of Medicine* 43:3 (May-June 1976): 207-218.  
<sup>e</sup>Arthur N. Rohl et al., "Asbestos Exposure During Brake Lining Maintenance and Repair," *Environmental Research* 12 (1976):110-128.

employees here are organized. The second type of shop is the automotive shops, frequently franchised, specializing exclusively in brake repair work, or brake repair and one or two other specialties. The majority of employees in this type of shop are also not organized. Shops of this type complete on average in excess of 50 brake jobs per week. The exposure of mechanics in these shops is greater than in the shops of the first type simply because of the higher frequency of operations. The third type of shop is the service department for the large automotive fleets. This includes the shops of major trucking companies and urban transit operators. In a large shop of this type, there may be a separate brake department where the workers deal only with brakes. It is in such shops that it is likely that a substantial volume of bevelling and grinding of new brake linings will be performed.

Brake jobs involving the installation of new brake linings in the first two types of shops will seldom require manual modification of the linings. This is because for virtually all passenger vehicles and small trucks undergoing brake repair in these shops, pre-machined linings (i.e., linings which are manufactured to conform to the exact dimensions of the brake drum) are available and only infrequently will manual modification be required to fit the relined shoe to the drum. For those operations using pre-machined linings, it would be unlikely that more than 5% of all relined brake shoes would require manual modifications to fit the drum. Thus, the major opportunity for exposure to brake dust is removed. However, there is still potential for exposure to brake wear debris in these shops.

While pre-machined brake linings are available for the larger vehicles repaired in the third type of shop, some fleet owners stock only one oversized brake lining size and alter the linings to meet the specific size requirements of the brake drums being repaired. In these shops, we would expect that a number of employees would engage continuously in grinding and bevelling of drum brake linings.

Mechanics repairing drum brakes may be protected from dust exposure in two ways. A high efficiency particulate air (HEPA) filtered vacuum may be used to remove wear debris from brakes, instead of blowing the debris out with an air hose. Alternatively, wet cleaning methods may be used either by wiping the drum and assembly with a damp cloth or by directing pressurized water or brake shoe spray into the drum. Bragg discussed the use of an inexpensive spray with a bowl to collect the contaminated liquid. Brake washer systems, including the liquid spray hose and trolley, are available for about \$200.<sup>74</sup>

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<sup>74</sup>Bragg, *The Technical Feasibility and Cost of Controlling Workplace Exposure to Asbestos Fibres*, p. 90.

## G.2 Shipyard and Railroad Exposure

Shipbuilding and ship repair constitute another activity in which workers may be exposed to airborne asbestos fibres. Since before World War II, fireproofing and thermal insulation, similar to the insulation sprayed in buildings in the 1950s and later years, was sprayed onto metal surfaces and otherwise installed in ships. Exposed workers would include those applying the insulation, those working on the ship in the vicinity of the spraying, and some trades who worked on the ships after the insulation was installed. We do not have data on the intensity of shipyard worker exposures, but they might be comparable to those of insulation workers, discussed in Chapters 9 and 10. Table 6.13 shows employment in shipyard work in Ontario from 1939 to the present. This employment grew substantially during World War II, reaching a peak of almost 9,000 workers in 1943–1944. We have no way of knowing what proportion of this workforce was exposed to asbestos. By the 1950s, employment was about one-quarter of its peak level, and it is now less than 2,000 workers. War-time work included the construction of corvettes and minesweepers for the Canadian, British, and American Navies.

Railroad vehicle construction and maintenance work has also been a source of worker exposure to asbestos. The boilers and fireboxes on steam locomotives were frequently covered with asbestos block insulation, similar to the insulation used on steam boilers in buildings. (See Chapters 9 and 10.) Construction of steam locomotives therefore requires the installation of asbestos insulating block. From time to time, the locomotive boiler would have to be re-insulated, which involved removing the metal jacketing around the insulation, removing the asbestos block insulation, repairing the boiler and piping as necessary, and then re-insulating the boiler and piping. All workers involved in these activities suffered some possible exposure to asbestos. We have not found data on the intensity of this exposure, but it might be of the same order of magnitude as that for insulation workers dealing with boilers and pipes in buildings, which can be quite considerable. (See Chapters 9 and 10.) In the United States, asbestos-related disease has been found in railroad workers engaged in locomotive maintenance.<sup>75</sup> We have not found estimates of the number of railway workers so exposed in Ontario.

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<sup>75</sup>Martin-Jose Sepulveda, "Roentgenographic Evidence of Asbestos Exposure in a Select Population of Railroad Workers," Morgantown, West Virginia, NIOSH, July 1982. (Mimeographed.); and Ronald L. Motley and Richard H. Middleton, Jr. "Asbestos Disease Among Railroad Workers: Legacy of the Laggin' Wagon," *Trial* (December 1981): 39–44.

**Table 6.13**  
**Employment in Ontario Shipyards, 1938-1980**  
**(Production Workers)**

Year	Number Employed
1938	551
1939	430
1940	NA*
1941	NA
1942	6,283
1943	8,914
1944	8,905
1945	5,103
1946	2,246
1947	2,171
1948	2,872
1949	2,308
1950-1954 (Average)	2,944
1955-1959 (Average)	1,819
1960-1964 (Average)	1,857
1965-1967 (Average)	2,060
1968-1973	NA
1974	1,668
1975-1979 (Average)	1,814
1980	1,942

**Note:** \*NA means data not available.

**SOURCE:** Statistics Canada, Catalogue 42-206, *Employees and Their Earnings in the Shipbuilding Industry*.

For 1937-1948, data are from Statistics Canada, Census of Manufactures.

## **Chapter 7    Control Limits for Fixed Place Industry**

### **A. Introduction**

In this chapter we will develop our recommendations concerning the regulation of asbestos in fixed workplaces by way of prohibition or of control limits governing worker exposure. The first step is to analyze, in Section B, the measurement methods used to determine worker exposure to asbestos. In Section C we use some of the epidemiological studies discussed in Chapter 5, and models developed in the Appendix to the present chapter, to estimate the risks of respiratory cancer that might result from applying alternative control limits. In Section D we review current control limits in several jurisdictions. In Section E we consider the criteria that should be used to determine workplace control limits in general, and asbestos control limits in particular. In Section F we apply these criteria to our quantitative risk assessment, enriching this assessment with other data and conclusions from Chapter 5, and we prescribe regulatory responses that differ for different industrial processes. Finally, in Section G we discuss the special case of regulating the asbestos exposures of automotive brake mechanics.

### **B. Measurement of Asbestos Fibres in the Workplace**

#### **B.1 Objectives of Workplace Measurement**

The purposes of measuring workplace asbestos dust levels are to determine the exposure of workers to health-related risks and to determine compliance with health-related exposure control limits. Thus, the design of a measurement technique should depend upon the answers to some of the medical questions considered in Chapter 5. It is generally accepted that the health risk from asbestos fibre exposure increases with the quantity of asbestos to which the individual is exposed, although there is considerable

debate on whether the relationship is linear or otherwise. We have discussed whether the degree of risk presented by a given fibre concentration in the air is affected by the type of fibre or the length of fibre. Because we have accepted both of these propositions, it would be useful to measure both length and fibre type. There is debate on whether health risks depend only upon the total cumulative exposure of the individual, or whether they depend upon the time profile of that exposure. In particular, some researchers believe that a given dose in a short, intense concentration might be more harmful than the same dose spread over a longer period of time. Thus, it may be useful to gather information on the time profile of worker exposure.

While a measurement technique might usefully gather all of the above information, it should be sufficiently economical to allow reasonably frequent measurement, and it should provide reasonable accuracy (ability to provide the correct measurement) and precision (ability to repeat a given measurement when there is no change in the underlying phenomenon). The measurement technique should also allow one to compare current measurements with previous measurements to determine whether exposures are rising or falling. Finally, a technique that allows the underlying information to be preserved for a long period of time will facilitate future studies of the data.

We have heard many arguments about the limitations of current techniques for measuring asbestos fibre concentrations at low concentration levels, an issue that will be discussed in detail below. We believe that if health and other considerations require a control limit that is below the level that can be adequately measured by current technology, the solution is not to raise the control limit to a level that can be measured, but rather to consider prohibition of any exposure to the substance until such time as measurement technology is available that can be used to enforce compliance with the desired control limit. This should encourage the development of such improved measurement technology.

## **B.2 The Membrane Filter Method**

Historically, occupational exposure to asbestos was based upon visual counts of asbestos dust particles using various dust sampling techniques. In the late 1960s, the technology of measurement improved and changed from a count of dust particles to an actual count of asbestos fibres. For measurement purposes, an asbestos fibre was defined in accordance with common

international practice as a fibre longer than 5 microns,<sup>1</sup> whose length to diameter ratio (aspect ratio) was at least 3 to 1. This definition originated in the United Kingdom, having been somewhat arbitrarily selected by three asbestos manufacturers who collaborated on the matter. It was apparently chosen to facilitate counting using the optical microscope, and because it was thought that the development of asbestosis was related to longer fibres. Because some researchers conclude that fibres with diameters exceeding about 3.5 microns are not respirable, some versions of the measurement rules specify a maximum diameter of 3 microns or 5 microns.

In the membrane filter method, a volume of air is drawn through a membrane filter by a pump. If the air is drawn from near the worker's face, it is a personal sample, otherwise it is an area sample. Asbestos fibres and other solids are collected on the membrane filter. The filter is removed from the sampler and taken to a laboratory where it is made transparent (cleared), mounted on a slide, and inserted into a microscope, usually a phase contrast microscope (PCM). An operator examines portions (fields) of the filter under the microscope and counts the number of fibres present, using elaborate rules to determine whether an object should be counted as a fibre. The average fibre concentration over the entire filter can be estimated from the number of fibres in the fields actually counted, and from this the concentration of fibres in the air where the sample is taken can be estimated.

The membrane filter method has a number of limitations as a means of determining the exposure of workers to asbestos fibres. However, no alternative measurement method seems to be sufficiently attractive, according to the criteria suggested above, to be a logical candidate for replacing the membrane filter method. Electron microscope methods may provide greater accuracy or better fibre identification, but they are currently considerably more expensive. In addition, because the electron microscope can detect fibres not visible in the optical microscope, electron microscope counts are not directly comparable to the optical fibre count data accumulated over the last fifteen years and to control limits enforced by optical fibre counts. However, it is possible to compare fibre counts using both methods if appropriate adjustments are made. (See Chapter 9, Section C.) Another method for measuring low concentrations of asbestos fibres in the air is gravimetric or mass measurement, discussed in Chapter 9, Section C. While this mass measurement might be applied to workplaces with low fibre concentrations, there is again the problem of converting mass measurements to an equivalent optical fibre count. Without such a conver-

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<sup>1</sup>Eric J. Chatfield, *Measurement of Asbestos Fibre Concentrations in Workplace Atmospheres*, Royal Commission on Asbestos Study Series, no. 9 (Toronto: Royal Commission on Asbestos, 1982), p. 4. The correct technical term for one-millionth of a metre is micro-metre, but we will use the more familiar term, micron.

sion it is impossible to know whether a gravimetric reading represents a greater or lesser exposure than the current control limit expressed in fibres per cubic centimetre, measured optically. Furthermore, there is no generally accepted method for analyzing gravimetric samples, and each researcher currently uses a different method, so that their results are not comparable. Thus, it seems appropriate that the regulation of asbestos in the workplace continue for the near future to rely on the membrane filter method.<sup>2</sup>

In Section F of this chapter we conclude that in some cases the control limit for asbestos should be set at a concentration below that which can reliably be measured using the membrane filter method. This causes such uses of asbestos to be prohibited until measurement technology is available that allows these control limits to be reliably enforced. If the industry believes that the low control limits can be achieved, and that there is substantial economic value to using asbestos in this way, then industry may develop improved measurement techniques that would demonstrate compliance with these control limits. Section 17 of the Regulation Respecting Asbestos states that “. . . the methods and procedures that may be used or adopted may vary from the codes issued by the Ministry if the protection afforded thereby or the factors of accuracy and precision used or adopted are equal to or exceed the protection or the factors of accuracy and precision in the codes issued by the Ministry.”<sup>3</sup> We interpret this section to mean that the Ministry would allow some fibre measurement method other than the membrane filter method specified in the Code for Measuring Airborne Asbestos Fibres to be used if the Ministry was satisfied that the alternative measurement technique was appropriate.<sup>4</sup> We therefore recommend that:

*7.1 Whenever control limits that cannot be enforced by present measurement techniques are adopted, the Ministry of Labour should emphasize that section 17 of the Regulation Respecting Asbestos allows the substitution of alternative measurement techniques if the Ministry is convinced that the substitute techniques satisfy the criteria of section 17 of the Regulation.*

### **B.3 Recommended Improvements to the Membrane Filter Method**

In a study prepared for this Commission, Dr. Eric J. Chatfield discussed some of the problems with the existing application of the mem-

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<sup>2</sup>Ibid., sec. 5.1.

<sup>3</sup>Regulation Respecting Asbestos, O. Reg. 570/82, made under the *Occupational Health and Safety Act*, R.S.O. 1980, c. 321.

<sup>4</sup>See Code for Measuring Airborne Asbestos Fibres, in Regulation Respecting Asbestos.

brane filter method in Ontario.<sup>5</sup> The Ontario Ministry of Labour method of preparing the membrane filter to produce microscope slides uses dimethyl phthalate and dimethyl oxalate and is required by the Code for Measuring Airborne Asbestos Fibres, section 2(2)(f). This is the mounting method used by the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) in the United States. Unfortunately, the method does not yield a durable slide, and the fibres must be counted within two days, or they cannot be counted at all. In contrast, the Asbestos International Association (AIA) preparation method, using acetone-Triacetin, produces a durable slide that also yields better fibre resolution, allowing more of the fibres to be seen and counted.<sup>6</sup> A minor drawback to the acetone-Triacetin method is that it requires the use of a fume hood and must therefore be performed in a laboratory.<sup>7</sup> We believe that durability and resolution are important. We therefore recommend that:

*7.2 The Ministry of Labour mounting method should be amended to replace the dimethyl phthalate and dimethyl oxalate preparation step with the acetone-Triacetin preparation step.*

The improved resolution of this preparation should improve the accuracy of fibre counting in Ontario. We believe that there would be some value in preserving counted slides for a period of time for use in auditing the accuracy of reported fibre counts, as possible evidence in any prosecutions for violation of the control limit, and for research that requires more information than is provided on the data sheets prepared by fibre counters. For example, old slides could provide a data base for analysis of the fibre dimensions found in different workplaces. However, because under section 15(1) of the Regulation Respecting Asbestos the records of work exposures must be maintained for up to forty years, we doubt that the permanent storage of slides is necessary. Storage for a five-year period should provide sufficient time for preserved slides to serve their purposes. We therefore recommend that:

*7.3 The Ministry of Labour should require that all slides and remaining filter segments that represent workplace exposures in Ontario, whether counted by the Ministry of Labour or by a private firm, be catalogued and stored in Ontario for a period of five years after the sample is taken.*

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<sup>5</sup>Chatfield, *Measurement of Asbestos Fibre Concentrations in Workplace Atmospheres*, sec. 2.

<sup>6</sup>Ibid., p. 8.

<sup>7</sup>Gyan S. Rajhans and John L. Sullivan, *Asbestos Sampling and Analysis* (Ann Arbor, Michigan: Ann Arbor Science Publishers Inc., 1981), p. 113.

Dr. Chatfield has stated that "It has been demonstrated . . . that incorrect alignment of the phase contrast microscope can result in significant reductions in fibre counts . . . . The AIA method and the proposed ISO/DIS [International Organization for Standardization/Draft International Standard] method both clearly specify the use of test slides to ensure adequate microscope resolution. The other published methods do not."<sup>8</sup> The Regulation Respecting Asbestos does not incorporate any test of microscope resolution. We recommend that:

*7.4 The Ministry of Labour method should be modified to incorporate tests of microscope resolution.*

Dr. Chatfield indicated that the selection of the microscope graticule can influence the accuracy of the fibre count.<sup>9</sup> Only the Walton-Beckett graticule has been designed specifically for fibre counting. It is the only graticule that does not demand visual interpolation by the operator to determine whether fibres exceed the critical dimensions. In both the AIA and ISO/DIS methods, this graticule has been adopted as the standard. The Code for Measuring Airborne Asbestos Fibres requires the use of the Patterson Globe and Circle reticle.<sup>10</sup> We recommend that:

*7.5 The Ministry of Labour should specify the Walton-Beckett graticule exclusively in the Code for Measuring Airborne Asbestos Fibres.*

To control for variability in counting among operators from one time to another, the U.S. Public Health Service and the National Institute for Occupational Safety and Health (USPHS/NIOSH) recommend that one of 10 samples should be recounted blind, so that the operator does not know that the slide is being recounted, either by the same operator or by a second operator. This provides a specific test of the repeatability of the fibre counting.

The Ministry of Labour requires recounting of only one sample in 20, or one per batch, whichever is lower, and allows recounting by the same operator.<sup>11</sup> Dr. Chatfield has noted that recounting by the same operator ignores the most significant variability factor.<sup>12</sup> We recommend that:

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<sup>8</sup>Chatfield, *Measurement of Asbestos Fibre Concentrations in Workplace Atmospheres*, p. 9.

<sup>9</sup>*Ibid.*, pp. 59-60.

<sup>10</sup>Code for Measuring Airborne Asbestos Fibres, s. 2(2)(a)(iv).

<sup>11</sup>*Ibid.*, s. 4(4).

<sup>12</sup>Chatfield, *Measurement of Asbestos Fibre Concentrations in Workplace Atmospheres*, p. 10.

**7.6 *The Ministry of Labour method should be modified to provide a more rigid system of quality assurance, including the use of blank filters and recounting by other operators.***

Because there are many objects of a variety of shapes on a filter, it is important to have a consistent set of rules telling operators what should be counted as a fibre and what should not. While there is room for much debate as to what should properly be counted, there is some advantage in following internationally accepted procedures on this matter. According to Rajhans and Sullivan, the AIA reference method has incorporated the best components of counting methods from the United Kingdom, the United States, and Australia, providing detailed fibre counting criteria that should reduce counting variability.<sup>13</sup> We recommend that:

**7.7 *The fibre counting criteria published in the Asbestos International Association's (AIA) reference method should be adopted by the Ontario Ministry of Labour as an interim measure since they represent a current level of international consensus. If and when agreement is reached on counting criteria to be adopted for the International Organization for Standardization/Draft International Standard (ISO/DIS) method, these should then be considered for adoption by Ontario.***

Because of subjective elements in determining what to count as a fibre, and because of variations in analytical and laboratory techniques, there may be considerable differences in the number of fibres counted on a given slide by various operators or various laboratories. These variations can occur even when the operators are nominally using the same counting rules and techniques. Dr. Chatfield reported that when a set of filters is distributed to different laboratories, or even to different operators within a given laboratory, the resulting fibre counts are highly variable.<sup>14</sup> Variations of a factor of 10 have occurred between individual counters. Systematic variations of a factor of 3 have been observed between laboratories that were apparently using identical analytical procedures. Dr. Chatfield reported on an international round-robin trial in which maximum fibre counts ranged from 2.8 to 6.2 times as large as the lowest fibre count for the same filter.<sup>15</sup> All of these measurement problems become more serious as the workplace control limit is reduced and the fibre levels that must be measured decline.

The only means of reducing these variations is to conduct round-robin trials in which a set of slides is sent around to various counters, the fibres

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<sup>13</sup>Rajhans and Sullivan, *Asbestos Sampling and Analysis*, p. 101.

<sup>14</sup>Chatfield, *Measurement of Asbestos Fibre Concentrations in Workplace Atmospheres*, pp. 24-25.

<sup>15</sup>*Ibid.*, Table 3, p. 25.

counted, and the results reported. Where substantial discrepancies exist among individuals or laboratories, some discussion must take place in which the source of the discrepancy is identified, and agreement is reached as to how to eliminate it. Dr. Chatfield has suggested that the use of a central reference system as adopted in the United Kingdom and in Sweden can reduce the inter-laboratory variability.<sup>16</sup> The Ministry of Labour could select its own laboratory, some other Ontario laboratory, or conceivably a non-Ontario laboratory to act as a central reference laboratory. The central reference system would conduct round-robin trials among fibre counters and certify those whose performance is acceptably close to that of the average of the group or to that of some reference operator or operators.

Every attempt should be made to include worker representatives from Ontario asbestos manufacturing plants among such certified operators where the volume of measurements warrants it. We believe that this will help to ensure that the workers whose health depends upon the maintenance of low asbestos fibre levels will view the measurements taken in their workplaces as reliable. We therefore recommend that:

- 7.8 The Ministry of Labour should identify a laboratory to take responsibility for standardizing methods of asbestos fibre counting for workplace samples in Ontario and to certify individuals whose performance is judged by this laboratory to be satisfactory. Every attempt should be made to include worker representatives from Ontario asbestos manufacturing plants among such certified operators where the volume of measurement warrants it.*

## **B.4 Sampling and Measurement Errors and Compliance**

The purpose of workplace measurements is to determine the true total exposure over time of workers to asbestos fibres in the air.<sup>17</sup> The actual measurement is based upon samples from a few workers over a few hours out of their working year. Thus, the measurements that are taken provide only an estimate of the true exposure of the worker. Sources of error between the measurement and the worker's actual exposure include the following:

- (i) The period sampled may not represent the exposure of the worker himself.

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<sup>16</sup>Ibid., p. 34.

<sup>17</sup>Ideally, workplace measurements should determine the true exposure over time of workers to those asbestos fibres that are most toxic. Any exposure measure is only an index of the hazard actually experienced.

- (ii) The sampling method may not contain a representative sample of the air the worker breathes.
- (iii) The sampling pump may not be properly calibrated or operated.
- (iv) The preparation of the filter may lose some fibres.
- (v) Because only portions of a given filter are actually counted, the fields counted may not accurately represent the fibre density on the entire filter.
- (vi) The operator's fibre count may over- or underestimate the actual number of fibres present.

Thus, a single fibre count is only an estimate, and perhaps not a very good estimate, of the actual exposure of the worker to asbestos fibres.

One solution to this problem is to obtain more samples. If each worker were monitored continuously, then the first problem would be solved and there would be a sufficient number of measurements so that the other errors might tend to cancel each other out. This is impractical, however, because of the cost and inconvenience to the worker, and thus we must assume that the total number of measurements taken will continue to be rather limited.

#### **(a) The Confidence Interval of a Measurement**

This leaves the question of what one can properly infer from the analysis of one or more samples at a work station. The fibre count from a single sample is the best estimate of the actual exposure of the worker. The average fibre count from a number of samples is the best estimate of the average exposure at the work station.<sup>18</sup> The accuracy of this estimate can be described by the "95% confidence limit" of the estimate. The 95% confidence limit is the range of values within which the actual exposure will be contained 95% of the time, or 19 out of 20 times. If the measurement is very precise, then the 95% confidence limit may be a very narrow range of values around the sample mean. If the measurement is highly imprecise, then the 95% confidence interval may be a very wide range around that number. A study by the Air Monitoring Committee of the Asbestos Infor-

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<sup>18</sup>The best estimate of the average exposure  $U$ , given a set of sample readings  $x$ , is obtained first by taking the log of each sample reading, since the exposures are approximately log-normally distributed. Let the log of  $x$  be called  $y$ . The mean of the sample logs is  $Y$ , and the variance of the  $y$  is  $s^2$ . The best estimate of the true average exposure  $U$  is:  $U = \exp. (Y + 1/2 s^2)$ . See J.A. Greenwood and H.O. Hartley, *Guide to Tables in Mathematical Statistics* (Princeton, N.J.: Princeton University Press, 1962), p. 412. See also, John M. Dement et al., "Estimates of Dose-Response for Respiratory Cancer Among Chrysotile Asbestos Textile Workers," *Annals of Occupational Hygiene* 26:1-4 (1982): 872.

mation Association/North America (AIA/NA) has shown that if a single 8-hour sample yields a fibre count of 1 fibre per cubic centimetre (f/cc), then it may be 95% certain that the true fibre count is between 0.26 and 2.73 f/cc.<sup>19</sup> (See Figure 7.1.)

We have seen that a single fibre measurement may give a very imprecise estimate of the true exposure of the worker. The estimate of the worker's actual exposure can be improved by taking additional samples. The width of the confidence limit for the estimate of the true exposure is inversely proportional to the square root of the number of measurements taken, so that quadrupling the number of measurements will divide the confidence limit approximately in half. (See the dotted line in Figure 7.1.)<sup>20</sup> If some of the variability in the fibre measurements arises specifically from errors in fibre counting, then repeated counting of a given filter may allow some improvement in the confidence interval of the estimate. If one is interested in estimating the worker's average exposure, adding independent sample measurements or fibre counts is an important means of improving the precision of this estimate.

### (b) The Detection Limit

The detection limit of a measurement method is the lowest concentration at which the method may reliably be used to determine whether the contaminant is present or not. The errors discussed above contribute to causing the detection limit to be some positive concentration and not zero. The possibility that asbestos fibres may be found on slides even when there was no asbestos in the air means that low fibre counts may erroneously be interpreted as demonstrating that asbestos was in the air. Even blank slides will often yield a fibre count of a few fibres in 100 fields. The AIA/NA study concluded that the detection limit for the membrane filter method is no lower than 0.1 f/cc.<sup>21</sup>

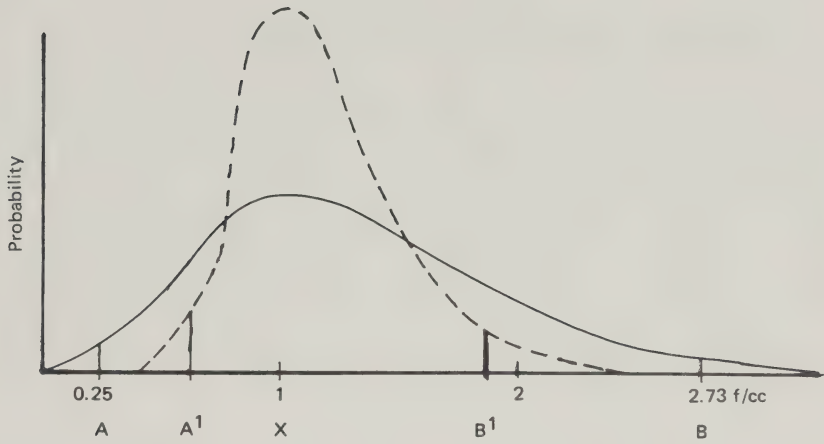
The detection limit is the lowest level for which the *presence* of asbestos can reliably be measured. The *quantity* of asbestos present can only be estimated accurately at concentrations well above the detection limit. Thus, the lower limit for accurate measurement of asbestos fibre concentrations is well above 0.1 f/cc. Since for any true exposure level, some measured fibre

<sup>19</sup>Asbestos Information Association/North America, *A Study of the Empirical Precision of Airborne Asbestos Concentration Measurements in the Workplace by the Membrane Filter Method*, prepared by the Air Monitoring Committee of the AIA/NA, Dr. Harrison B. Rhodes, Chairman (Arlington, VA: AIA/NA, June 1983), Table 8.1.

<sup>20</sup>The confidence limit would be divided precisely in half if the measurements were independent and their probability distribution were normal.

<sup>21</sup>Asbestos Information Association/North America, *A Study of the Empirical Precision of Airborne Asbestos Concentration Measurements in the Workplace by the Membrane Filter Method*, pp. 8–22.

Figure 7.1  
Distribution of Probable Values of True Exposure Given a Measurement X



**Notes:** A,  $A^1$  = lower confidence limit.  
B,  $B^1$  = upper confidence limit.

counts will be above and some below the true level, a firm that wishes to be in compliance with a control limit 95% of the time must produce an average fibre level that is below the control limit. Thus, the lowest control limit for which compliance can reliably be proved must be well above the detection limit.

### (c) Average Exposures Under Control Limits

What is the relationship between the average exposure of a worker and a control limit that is enforced? Dr. Chatfield has shown that given the variability of fibre readings taken in an Ontario brake plant, if the plant were to exceed the control limit no more than 5% of the time, its average fibre concentration would have to be between one-half and one-quarter of the control limit or less, depending on the variability of these measurements.<sup>22</sup> (See Figure 7.2.) The AIA/NA study demonstrated that given the variability of its data, in order to ensure that the upper confidence limit was below 1 f/cc, that is, to ensure that there was less than a 2.5% chance that the true fibre level exceeds 1 f/cc, a single 8-hour time-weighted average (TWA) sample would have to be about 0.30 f/cc or less.<sup>23</sup> Table 6.7 in Chapter 6 shows that average fibre counts could lie between 0.5 and 1.0 f/cc when 10 to 20% of those counts exceeded 2 f/cc. The United Kingdom Advisory Committee on Asbestos reported that in friction products a *median* fibre count of 0.2 f/cc could yield 95% of all counts less than 2 f/cc, with 85% less than 1 f/cc.<sup>24</sup> Thus, if enforcement of a control limit of 1 f/cc meant that the Ministry of Labour allowed 10 to 20% of all observed fibre counts to exceed 1 f/cc, the average worker's exposure might be between 0.25 and 0.5 f/cc. With more stringent enforcement, so that 5% or less of all fibre counts exceeded the 1 f/cc control limit, the average worker exposure might be less than 0.25 f/cc.

Dr. Chatfield concluded that for a control limit of 0.2 f/cc, compliance cannot be demonstrated on the basis of a 90-minute air sample.<sup>25</sup> Compliance with the 1 f/cc control limit can be demonstrated if sufficient quality control is used in the analytical techniques. Dr. Chatfield regards the demonstration of compliance at the 0.5 f/cc level as possible but somewhat uncertain.<sup>26</sup> Dr. Gerald R. Chase and Dr. Harrison B. Rhodes

<sup>22</sup>Chatfield, *Measurement of Asbestos Fibre Concentrations in Workplace Atmospheres*, Table 7, p. 43.

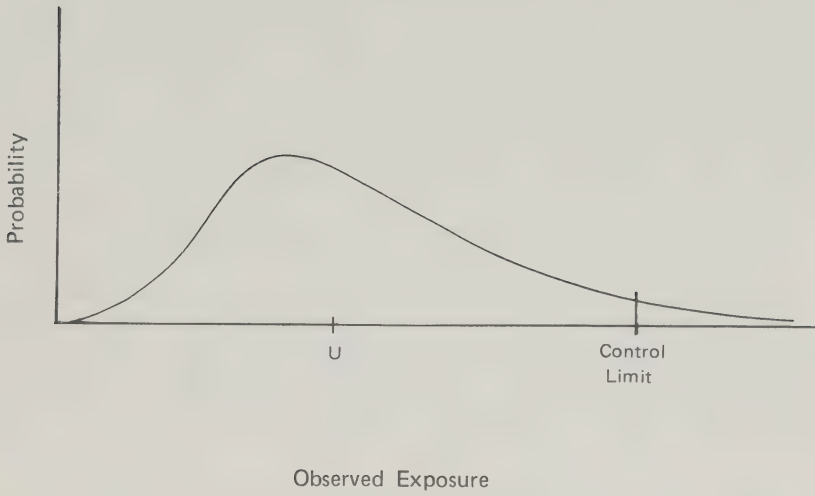
<sup>23</sup>Asbestos Information Association / North America, *A Study of the Empirical Precision of Airborne Asbestos Concentration Measurements in the Workplace by the Membrane Filter Method*, Table 8.1.

<sup>24</sup>U.K., Advisory Committee on Asbestos, *Asbestos — Volume 1: Final Report of the Advisory Committee* (Simpson Report), William J. Simpson, Chairman (London: Her Majesty's Stationery Office, 1979), Figure 1, p. 17.

<sup>25</sup>Chatfield, *Measurement of Asbestos Fibre Concentrations in Workplace Atmospheres*, p. 44.

<sup>26</sup>*Ibid.*

Figure 7.2  
Probability of Observing Various Exposures Given Average Exposure  $U$



agreed that the lowest control limit that would allow an employer to be 95% certain that no more than 5% of employee exposures exceeded the control limit would be between 0.5 and 1.0 f/cc.<sup>27</sup>

We, therefore, conclude that using the membrane filter method, it is not possible to use single samples to demonstrate reliably compliance with a control limit of 0.1 f/cc and 0.2 f/cc. We conclude that demonstrating compliance with a control limit of 0.5 f/cc might be possible with present analytical methods, but is subject to considerable uncertainty. Averaging a number of samples might be required to test compliance reliably at the 0.5 fibre level. Demonstrating compliance with a control limit of 1.0 f/cc is possible using single samples and present measurement methods.

#### (d) Sampling Frequency for Enforcing Control Limits

The Ministry of Labour has recognized the variability in the exposure of individual workers over the course of a typical work week. The Code for Measuring Airborne Asbestos Fibres in the Regulation Respecting Asbestos states that a sufficient number of samples of a worker should be taken to calculate a time-weighted average concentration, and these samples must be representative of the worker's exposure.<sup>28</sup> The time-weighted average, to which the control limits of section 4 of the Regulation Respecting Asbestos are applied, are to be calculated as a weighted average of these sample exposures, where each exposure is weighted by the percentage of the week that the worker spends in activity.<sup>29</sup>

Most jurisdictions use a single measurement of the worker's exposure, typically based on an air sample gathered over a period of 1 to 4 hours, to determine whether the control limit has been exceeded or not. We see both advantages and disadvantages to the Ministry of Labour's calculation of a time-weighted average based upon one or more independent samples. In theory, the use of multiple samples allows an accurate estimate of the

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<sup>27</sup>Ontario, Royal Commission on Asbestos, Exhibit II-39, Tab 11 [hereafter RCA Exhibit], in Ontario, Royal Commission on Asbestos, Transcript of Public Hearings [hereafter RCA Transcript], Evidence of Dr. Gerald R. Chase and Dr. Harrison B. Rhodes, 14 August 1981, Volume no. 27, p. 22: Gerald R. Chase and Harrison B. Rhodes, "Measurement of Asbestos Levels in the Workplace," [Arlington, VA], Asbestos Information Association/North America, 14 August 1981. (Mimeographed.)

<sup>28</sup>Code for Measuring Airborne Asbestos Fibres, s. 3(3)(i).

<sup>29</sup>The Schedule following the Regulation Respecting Asbestos provides in ss. 4 and 5 for the calculation of a time-weighted average:

4. The weekly exposure shall be calculated as follows:

$C_1T_1 + C_2T_2 + \dots + C_nT_n$  = cumulative weekly exposure, where  $C_1$  is the concentration found in an air sample and  $T_1$  is the total time in hours to which the worker is taken to be exposed to concentration  $C_1$  in a week.

5. The time-weighted average exposure shall be calculated by dividing the cumulative weekly exposure by 40.

worker's exposure over the course of a week, since exposure readings may be taken during each of several activities the worker may engage in, and each such exposure can be given a weighting according to how important that activity is over the course of the work week. Thus, if a worker performs a dirty job for 30 hours and a clean job for 10 hours, a 2-hour reading taken during each type of job yields a TWA that reflects the predominance of time spent in the dirty activity. Furthermore, since multiple samples are used to calculate the TWA, the variability in the TWA as an estimate of the worker's true exposure is reduced.

On the other hand, the time weighting which is theoretically attractive raises practical problems. Some concern has been expressed to this Commission that it will be difficult to determine the time weightings, and that industry may choose these in a way that will underestimate the time-weighted average. Prosecutions may be more difficult because of the complexity of the calculation. Worker interpretation of exposure data may be impeded because of the complexity of the calculation. Furthermore, since the variability of the time-weighted average is less than when single measurements are used, the average worker's exposure may be somewhat closer to the control limit than if single exposures were used for enforcement.

On balance, we have not heard sufficient objections to the Ministry's use of multiple samples for calculating a time-weighted average to lead us to reject this procedure as a basis for enforcing the control limit. However, we urge the Ministry to monitor the field experience with this measurement method and to determine whether the problems raised above are in fact serious. If they are, the Ministry should consider reverting to the use of individual samples to enforce the control limit. In its deliberations, the Ministry should find some guidance in the statistical analysis of sampling strategies contained in a manual published by the U.S. National Institute for Occupational Safety and Health.<sup>30</sup> Furthermore, in Section F of this chapter we endorse control limits on the assumption that average worker exposures will be less than or equal to half of the control limit. If the use of multiple samples in calculating the time-weighted average should allow average worker exposures to rise above half of the control limit, then the Ministry should take action to maintain those exposures at half the control limit or below.

Whether the worker's time-weighted average exposure is to be calculated from multiple samples, or from a single sample, there is still the question of how often such a time-weighted average should be determined for each worker. Should each worker be measured once a year, once a month,

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<sup>30</sup>Nelson A. Leidel, Kenneth A. Busch, and Jeremiah R. Lynch, *Occupational Exposure Sampling Strategy Manual* (Cincinnati, Ohio: U.S. Department of Health, Education and Welfare, National Institute for Occupational Safety and Health, 1977), chap. 3.

or once a week? Should some workers or work stations be measured more than others? The Regulation Respecting Asbestos, and the associated codes, give no guidance on this issue. We can see many factors affecting the choice of a measurement frequency. Measurement is more instructive where the exposures are highly variable than where they are steady. Measurement information is more useful where policies are available to reduce exposures than where no fruitful action can be taken as a result of learning actual exposure levels. If one is particularly interested in detecting control limit violations, then measurements should be more frequent where high readings are suspected. If one is interested in calculating average exposures, then measurements should be randomly distributed among workers and time periods. Measurements might be distributed among plant processes in proportion to the number of workers exposed in each process. More measurements will provide better information, but will raise the cost of the monitoring programme. We do not find in these multiple factors a basis for providing further guidance on the question of measurement frequency in the Regulation Respecting Asbestos. Perhaps the joint health and safety committee, in its participation in a monitoring programme, should consider the objectives it believes are important in its plant and should work to ensure that these are reflected in the choice of measurement frequency. More than this is needed, however, if we are to be confident that the monitoring programme is adequate.

We are convinced that the design of a sampling strategy is at least in part a statistical problem. The manual published by the U.S. NIOSH analyzed statistically the frequency and type of measurement necessary in order to achieve particular levels of confidence in estimating average or maximum worker exposures.<sup>31</sup> This manual was written as a guide for enforcing U.S. occupational health legislation. The principles presented, however, have some general applicability and may be useful for enforcing the Regulation Respecting Asbestos and other occupational health regulations in Ontario. The manual defined levels of accuracy that may be achieved by occupational monitoring, providing methodologies for determining how many measurements are required in order to achieve that degree of accuracy. We believe as a matter of principle that the monitoring programmes required for determining worker exposures to asbestos, and probably other toxic materials in the workplace, should be designed to fulfill some minimum requirements regarding the accuracy of the average exposures that may be calculated from those measurements and the likelihood that particularly high worker exposures have been detected. Achieving this end would require that the regulations specify, in some statistical fashion, the goals to be achieved by a monitoring programme. This Commission has not heard sufficient evidence on this issue to formulate a recommendation for the precise form that such a regulation should take.

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<sup>31</sup> Ibid.

We are, however, concerned by the enormous latitude provided by the Regulation Respecting Asbestos with regard to sampling, and we believe that this should be made more precise. We therefore recommend that:

- 7.9 *The Ministry of Labour should undertake a study of the relationship between the number of air samples taken and the distribution of those air samples among workers, work stations, and periods of the day or week, in order to determine the minimum requirements for an air sampling programme that will provide reasonable confidence that the data collected adequately reflect the maximum worker exposures in a workplace, the average exposure of those workers, and those work stations where particularly intensive monitoring may be desirable. This study should incorporate such statistical analyses as are necessary for the task. Upon completing the study, the Ministry should amend the Regulation Respecting Asbestos to provide more specific direction regarding the sampling programme that will satisfy that Regulation.*

#### (e) Sources of Bias in Measurements

This discussion has assumed that all measurement errors are random and are equally likely to overestimate or underestimate the true exposure. However, a survey by Professor Sally Luce and Professor Gene Swimmer, undertaken for this Commission, revealed worker allegations that recorded fibre counts underestimated true fibre concentrations.<sup>32</sup> The primary reasons offered were that the time and place of sampling were not representative of actual worker exposure. It was suggested that the dirtiest operations might be performed on the night shift when samples were never taken. It was suggested that the dirtiest machines were switched off during sampling periods. It was suggested that the plant might be cleaned up in anticipation of the visit of an inspector. While we cannot estimate the quantitative significance of these practices, we believe that it is prudent to assume that actual worker exposures may be somewhat understated by the analysis of air samples taken by the Ministry of Labour alone or by management if there is no effective worker input.

While future enforcement practices are uncertain, we conclude from the above analysis that the imposition of any control limit that is enforced so that only 10% or so of individual samples exceed the control limit will permit worker exposures that, over the course of a few weeks or months, will average half the amount of the control limit. Less strict enforcement of a control limit would allow greater worker exposures. If the average exposure were as high as the control limit, then as many as one-half of all individual samples taken would exceed the control limit, and we see no evidence

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<sup>32</sup>Sally Luce and Gene Swimmer, *Worker Attitudes About Health and Safety in Three Asbestos Brake Manufacturing Plants*, Royal Commission on Asbestos Study Series, no. 6 (Toronto: Royal Commission on Asbestos, 1982).

that this has occurred regularly in any Ontario workplace. The data of Chapter 6, Table 6.7 show that since 1972 the average number of samples exceeding the then existing 2 f/cc guideline ranged from 50% down to zero, with most industries reporting between 10 and 25% of samples exceeding the guideline. We believe that it is unlikely that worker exposures will exceed, on average, the control limit itself, unless enforcement is abandoned completely. Thus, when assessing the health effects of a control limit, we will calculate the disease resulting from a normal exposure, assuming an average of one-half the amount allowed by the control limit, and from a high exposure, assuming that the exposure equals the control limit itself.

## B.5 Measuring Fibre Size

The size of respirable airborne asbestos fibres in the workplace may range up to 3 to 5 microns in diameter and up to 50 or perhaps 100 microns in length. This range of sizes immediately presents problems for measuring fibre concentration: what size fibres should be counted? We measure asbestos fibre concentrations in order to predict possible health effects. Thus, ideally, we would like to measure those fibres that are particularly relevant for health effects, and to ignore all other fibres. The practical problems of pursuing this objective can be seen by considering two examples.

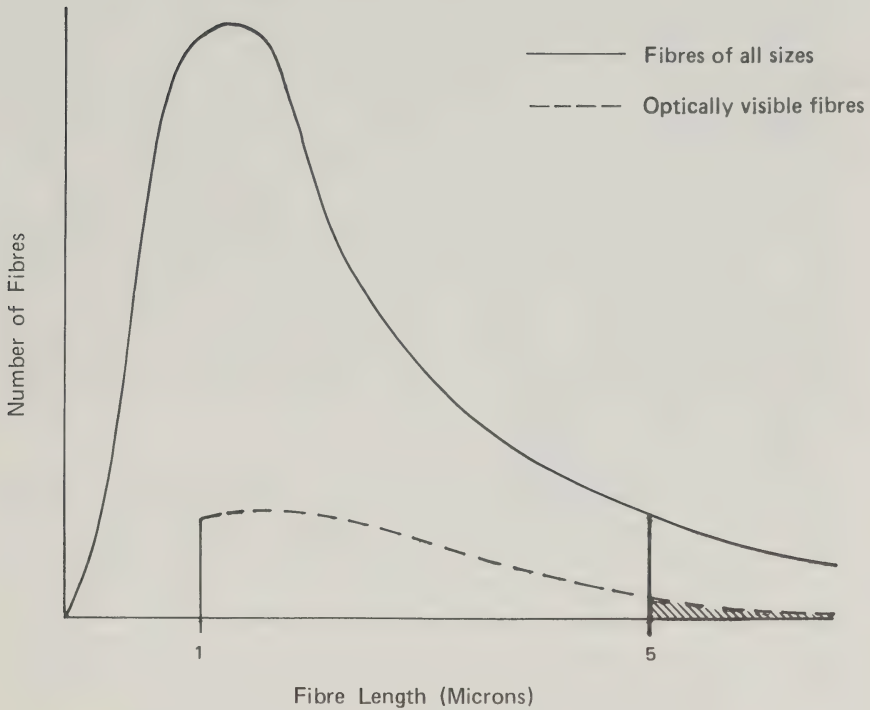
First, suppose that all asbestos fibres have the same effect regardless of size. In this case, counting the concentration of all asbestos fibres in the air would give us a measure that was proportional to the health effect of those fibres. It is impossible to count all fibres, however, because some are too small to be seen. The PCM cannot detect fibres thinner than 0.2 to 0.4 microns in diameter.<sup>33</sup> The transmission electron microscope (TEM), on the other hand, can detect unit fibrils of chrysotile, meaning that virtually all chrysotile fibres can be detected by TEM, if one is sufficiently patient to search for the small ones. The rules for counting fibres using a PCM exclude fibres shorter than 5 microns, or with an aspect ratio less than 3 to 1. Figure 7.3 shows a typical distribution of fibre sizes that might be present in the atmosphere and the much lesser distribution of fibre sizes that could be detected using optical methods. The shaded area under the optically visible line, above 5 microns in length, indicates the fibres that would actually be counted under current counting rules. This means in practice we count only a fraction of all airborne fibres, when using PCM.

If all asbestos sources generated identical fibre size distributions, then measuring a fraction of that distribution would give us a perfect index of the total number of fibres, and therefore the health hazard, assuming still

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<sup>33</sup>Eric J. Chatfield, *Measurement of Asbestos Fibre Concentrations in Ambient Atmospheres*, Royal Commission on Asbestos Study Series, no. 10 (Toronto: Royal Commission on Asbestos, 1983), p. 13.

**Figure 7.3**  
**Relationship Between Total Fibre Distribution and Optical Fibre Count**



**Note:** Shaded area shows optical fibre count.

**SOURCE:** Eric J. Chatfield, *Measurement of Asbestos Fibre Concentrations in Ambient Atmospheres*, Royal Commission on Asbestos Study Series, no. 10 (Toronto: Royal Commission on Asbestos, 1983), Figure 6, p. 15.

that all fibres are equally hazardous. There is, however, no reason to expect different dust sources to generate similar size distributions. Figure 7.4 shows that three sources might generate three very different distributions of fibre size, with source A producing primarily short fibres, while source C produces primarily long fibres. Suppose that a TEM, which can detect all fibres, were used to examine the three dust clouds depicted in Figure 7.4, applying the 5 micron length limit. The fibre count for source A would be very low, because only a few percent of its fibres are long enough to qualify for counting under the 5 micron length limit. The fibre count for source C, on the other hand, would be very large, since the vast majority of those fibres are longer than 5 microns. The fibre count for source B would be between that of A and C. Thus, three sources which generated identical total numbers of fibres would yield enormously different measured fibre counts under current counting rules that incorporate a 5 micron cutoff. If all fibres were of equal toxicity, the measurement only of longer fibres, or of fibres thick enough to be detected optically, provides us with an unreliable measurement that will yield varying fibre counts among different sources and that will not bear a consistent relationship to the total number of fibres.

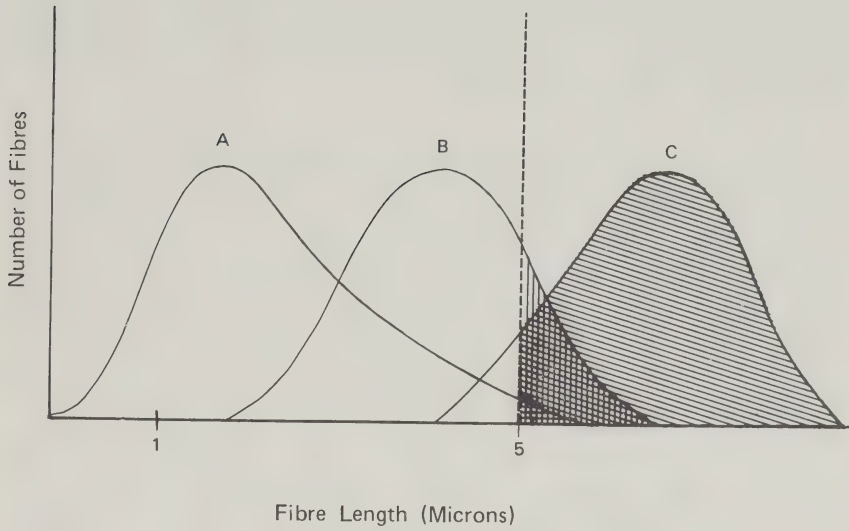
Consider a second case in which toxicity varies by fibre size. In this case it is not desirable to count all fibres. Instead, we would wish to count only those fibres of high toxicity. To take the worst example, suppose that while only fibres shorter than 5 microns were counted, only fibres longer than 5 microns were toxic. Under these assumptions, source C would present a far greater hazard than source A, yet the fibre count at source A would be enormously greater than at C. Such a measurement method would be useless for distinguishing situations of different hazard levels. On the other hand, if only fibres longer than 5 microns are toxic, and only fibres longer than 5 microns are measured, then the measure will correlate perfectly with the health hazard.

Thus, ideally, the rules for determining which fibres should be counted should be based on medical evidence of the toxicity of the various fibres. Dr. Friedrich Pott hypothesized that toxicity was a function of fibre length and diameter, with low levels of toxicity below lengths of 5 microns, and high toxicity levels around lengths of 20 microns.<sup>34</sup> (See Figure 7.5.) In Chapter 5 we conclude that toxicity increases with fibre length, so that the most relevant fibres are those longer than 5 or perhaps 8 microns. We also conclude that thin fibres are likely to be more hazardous than thick fibres. These conclusions suggest that counting fibres longer than 5 microns is a much better index of the health hazard than would be a count of fibres of all lengths. While a somewhat greater length cutoff, such as 8 microns,

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<sup>34</sup>Friedrich Pott, "Some Aspects on the Dosimetry of the Carcinogenic Potency of Asbestos and Other Fibrous Dusts," *Staub-Reinhalt. Luft* 38:12 (December 1978): 486-490.

Figure 7.4  
Three Examples of Fibre Length Distributions



might be still better, the evidence on this is not sufficient to give us confidence in recommending any change from the current 5 micron size limit used in the Ministry of Labour's code for measuring fibres. It follows that the mass concentration of asbestos in the air is a less accurate predictor of health effects than would be a count of fibres over 5 microns, since there is no reliable relationship between mass and the count of long, thin fibres we believe to be of greatest medical concern. Our conclusions also suggest that a count of fibres over 5 microns made by a TEM will be a better predictor of health effects than one made by the optical microscope, since more thin fibres will be detected by the TEM.

Ideally, it would be desirable to know the relative toxicity of fibres of all sizes and to measure the concentration of fibres of all sizes. Such data would allow one to construct a health index for any air sample by multiplying toxicity of each fibre size by its concentration. Our general conclusion that long, thin fibres are of greatest concern, however, is not sufficiently precise to provide a toxicity index that would allow us to recommend such a procedure. While the TEM may be able to measure more accurately than the PCM the long, thin fibres that are most toxic, there are serious barriers to the use of the TEM for workplace measurement. There is as yet no standardized method for TEM measurement, so fibre counts are not reproducible among laboratories. The TEM costs at least 10 times as much as the PCM for standard workplace monitoring. We believe that the use of PCM, with a 5 micron minimum size for fibre counting, represents a reasonable compromise between measuring accurately the fibres of greatest health consequence, and restraining the cost of such measurement in the workplace. For environmental measurement, where the fibre concentration is generally far lower than in the workplace, we believe that TEM measurement is essential. (See Chapter 9.)

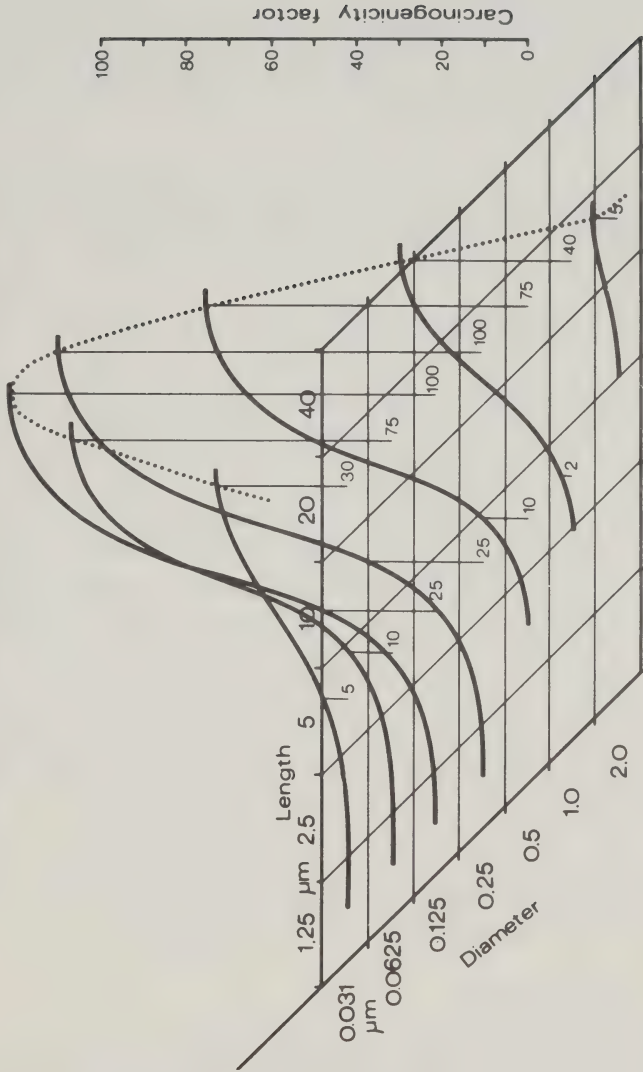
Because the length of maximum toxicity may be greater than 5 microns, it might be useful to provide, in addition to the count of fibres longer than 5 microns, a count of fibres longer than, for example, 15 microns. At present, however, we would not be able to make any particular use of such data. Furthermore, Dr. Chatfield has reported that if optical microscope operators were required to report separately the number of fibres longer than 20 microns, as well as the number longer than 5 microns, this would tend to reduce the reproducibility and accuracy of these results.<sup>35</sup> It is not, therefore, advisable to gather such additional length information routinely in workplace monitoring.

We have rejected the optical microscope for routine measurement of fibre size distribution because of low accuracy, and the TEM because of

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<sup>35</sup>Chatfield, *Measurement of Asbestos Fibre Concentrations in Workplace Atmospheres*, p. 55.

Figure 7.5  
Hypothesized Carcinogenic Potency as a Function of Fibre Size\*



**Note:**

\* Hypothesis on the carcinogenic potency of a fibre as a function of its size with some data on "carcinogenicity factors." (This three-dimensional model requires the fibre size of a sample to be divided into numerous categories. The size categories include three parameters: length, diameter, and the length/diameter ratio.)

SOURCE: Friedrich Pott, "Some Aspects on the Dosimetry of the Carcinogenic Potency of Asbestos and Other Fibrous Dusts," *Staub-Reinhalt. Luft* 38:12 (December 1978): 487 (Figure 3).

cost and the absence of standard methods. However, it is possible that the scanning electron microscope (SEM) can perform fibre counts at a cost little above that of an optical microscope, where fibre identification is not necessary. Dr. Chatfield has stated that the SEM can measure not only very thin fibres which are not visible in the optical microscope, but can also be used to report fibre length.<sup>36</sup> This method is not, however, proved for the enforcement of workplace control limits. It would be useful to develop better information on the size distributions of asbestos fibres in Ontario workplaces and to analyze the usefulness of the SEM as a workplace monitoring tool. We recommend that:

*7.10 The Ministry of Labour should conduct research using a scanning electron microscope alongside an optical microscope to explore the size distribution of fibres found in various workplaces.*

## **B.6 Measuring Fibre Type**

Dr. Chatfield concluded that the membrane filter method is not suitable for measuring separately the concentrations of different types of asbestos in mixed fibre atmospheres.<sup>37</sup> The membrane filter method is satisfactory, however, for measuring the total fibre concentration in such atmospheres. The Regulation Respecting Asbestos specifies different control limits for different fibre types, but requires that the total fibre count meet the most strict applicable control limit. Thus, it is unnecessary under the Regulation Respecting Asbestos to perform separate counts of chrysotile, amosite, and crocidolite. Our recommendations in Section F of this chapter will endorse these distinctions among fibre types and the application of the total fibre count in a mixed atmosphere to the relevant control limit. Therefore, we see no need to develop more sophisticated measurement techniques which can distinguish among fibre types in the workplace for routine enforcement of control limits.

## **C. Estimates of Future Disease from Future Workplace Exposure**

### **C.1 Introduction**

In Chapter 5 we review the medical evidence on the health effects of exposure to asbestos. This includes biological evidence, epidemiological studies, lung tissue studies, and animal studies. We conclude in that chapter that the risk of respiratory disease from exposure to any specified airborne

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<sup>36</sup>Ibid., p. 57.

<sup>37</sup>Ibid., p. 63.

asbestos fibre concentration differs among the three major fibre types and differs among processes generating the dust. Determining the control limits that should govern worker exposure to asbestos, however, requires quantitative estimates of the magnitude of disease that might arise from the specification of certain control limits. In this section we will use the major epidemiological studies, and the models described in the Appendix to this chapter, to produce a quantitative risk assessment. This risk assessment will be supplemented in Section F of this chapter with other data and conclusions from Chapter 5 to form a basis for recommending appropriate regulatory responses.

## C.2 The U.K. Advisory Committee Predictions

The incidence of asbestos-related disease that may result from future exposure to asbestos in the workplace may be predicted using a dose-response model and data from past studies which relate exposure and disease rates. The U.K. Advisory Committee report attempted to summarize the mortality experience shown in eleven studies of the health of asbestos workers.<sup>38</sup> The Advisory Committee concluded that if a 2 f/cc standard were adopted and complied with, and if employees were exposed over a 50-year working life, then the asbestosis incidence might be as great as 0.5% per annum, or it might be considerably less.<sup>39</sup> The Advisory Committee further concluded that the excess mortality from lung cancer after a 50-year working life might range from 0.1 to 2%, with dust levels ranging from 0.02 to 11 f/cc, the range being attributable to differing assumptions and different studies used as the basis for the forecast.<sup>40</sup>

We conclude in Chapter 5 that at cumulative exposures of 5 fibres per cubic centimetre-years (f/cc-yr) or as high as 25 f/cc-yr, asbestosis will be a very rare disease and may even in fact become a disease of the past. Even at these low doses, some fibrosis is possible, but clinical manifestations are not likely to develop in an individual's lifetime. In addition, it is unlikely that any significant number of workers would be exposed to 1 f/cc throughout their entire working career, since many work stations in the Ontario asbestos manufacturing industry today already are below that fibre level most or all of the time.

We conclude that with the recently adopted workplace control limit of 1 f/cc for chrysotile, and less for the other types of asbestos, the risk of asbestosis will be sufficiently small that it can be disregarded in comparison with the risk of cancer, to which we now turn.

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<sup>38</sup>U.K., Advisory Committee on Asbestos, *Asbestos — Volume 1: Final Report of the Advisory Committee*, Table 13, p. 51.

<sup>39</sup>*Ibid.*, paragraph 94, p. 55.

<sup>40</sup>*Ibid.*, Table 21, p. 62.

### C.3 Projecting Lung Cancer and Mesothelioma

#### (a) Worker Exposure Under Control Limits

Assessing the aggregate health effects of an occupational asbestos control limit requires making some assumptions about the worker and his exposure. We will define two cases for analysis: the short-term, normal exposure; and the long-term, high exposure.

As was pointed out in Section B of this chapter, it can be conservatively estimated that the average worker is exposed over the course of a year to an average of one-half the fibre concentration of the control limit if the control limit is enforced. If the control limit is not adequately enforced, then some workers may be exposed to more than one-half the control limit. We believe that it is reasonable to represent the exposure of a highly exposed worker over a year by a concentration equal to the control limit itself. The next step is to estimate the average duration of a worker's exposure to asbestos in his employment; that is, the number of years the worker is in asbestos manufacturing. At two Ontario brake plants, the average worker had been with the firm for about 10 years, although a third plant's workers averaged less than 4 years, and some workers had been at their plant for 25 years or more.<sup>41</sup> In testimony, we heard of a number of workers at the Scarborough plant of Johns-Manville who developed asbestos disease after 25 years of service.<sup>42</sup> There is little labour migration from one asbestos manufacturing plant to another, so time at a plant is a reasonable estimate of time in asbestos manufacturing. We will represent a short-term worker by an exposure duration of 10 years, and a long-term worker by an exposure duration of 25 years. While some workers may be exposed for more than 25 years, and others for less than 10 years, the vast majority of exposures should be within or below these limits. Coincidentally, our short-term exposure is exactly the minimum duration of exposure stipulated in the Ontario Workers' Compensation Board guideline for asbestos-related lung cancer claims.

Combining the exposure and the duration, the short-term, normally exposed worker would be exposed to a fibre concentration equal to one-half the control limit for a period of 10 years. The long-term, highly exposed worker would be exposed to a fibre concentration equal to the control limit

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<sup>41</sup>Luce and Swimmer, *Worker Attitudes About Health and Safety in Three Asbestos Brake Manufacturing Plants*, p. 4.2. A recent study of three U.S. asbestos manufacturing plants reported that the average tenure of workers was 8.7 years, 7.6 years, and 9.2 years. See Alison D. McDonald et al., "Dust Exposure and Mortality in an American Chrysotile Asbestos Friction Products Plant," *British Journal of Industrial Medicine*, in press, 1984, p. 6.

<sup>42</sup>See RCA Transcript, Submission by the Asbestos Victims of Ontario, 16 February 1981, Volume no. 1, especially pp. 153, 156, 163, 167, 176.

for a period of 25 years. We do not believe that exposures greater than the control limit are likely, absent a complete breakdown in vigilance regarding the hazards of asbestos.

We can assess the health effects of various control limits by applying the above conclusions about worker exposure to the dose-response estimates that have emerged from previous epidemiological studies. As a starting point, we will look at the effects of exposure to 2 f/cc for 50 years, which produces a cumulative exposure of 100 f/cc-yrs, a high exposure that has been referred to in many studies. We will also consider the exposure for a short-term, normally exposed worker resulting from a 1 f/cc control limit for 10 years, which yields a cumulative exposure of 5 f/cc-yrs. We finally consider the case of the long-term, high exposure worker under a 1 f/cc control limit for 25 years, which yields a cumulative exposure of 25 f/cc-yrs.

### **(b) Relative Risk Projections**

We asked Mr. Ronald J. Daniels and Professor Robin S. Roberts to analyze for this Commission major studies of asbestos workers for which there are reasonable data on the fibre levels to which workers were exposed. Their analysis, "Predicting Workplace Health Risks," appears as the Appendix immediately following this chapter.<sup>43</sup> Their summary of the health effects found in these studies is presented in Table 7.1. This table shows the risk of lung cancer, gastrointestinal cancer, mesothelioma, and asbestosis revealed by the studies conducted by: J. Corbett McDonald et al. [hereafter the J.C. McDonald study]; Vivian L. Henderson and Philip E. Enterline [hereafter the Enterline study]; Julian Peto (et al.) [hereafter the Peto study]; John M. Dement et al. [hereafter the Dement study]; Geoffrey Berry and Muriel L. Newhouse [hereafter the Berry study]; Murray M. Finkelstein [hereafter the Finkelstein study]; and Irving J. Selikoff, E.

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<sup>43</sup>See Ronald J. Daniels and Robin S. Roberts, "Predicting Workplace Health Risks," Appendix to Chapter 7 of this Report.

Cuyler Hammond, and Herbert Seidman [hereafter the Selikoff study].<sup>44</sup> The bottom of Table 7.1 reports the lung cancer rate alone as a function of fibre levels, showing the relative risks detected by the various studies. The relative risk is the ratio of the number of observed deaths to the number of expected deaths. The excess risk is the relative risk minus 1.0, expressed as a percentage.

In the Appendix to Chapter 7, Daniels and Roberts present an estimate of the relative risk of lung cancer from specified fibre exposures based on the dose-response relationships estimated from Table 7.1. This is summarized in Table 7.2. Consider the relative risk predicted for an exposure of 100 f/cc-yrs, the bottom line in this table. The J.C. McDonald data predict a relative risk of 1.02 to 1.046, for an excess risk of 2.0 to 4.6%. The Enterline data predict a relative risk of 1.069, for an excess risk of 6.9%. The Berry data predict a relative risk of 1.058, for an excess risk of 5.8%. The most alarming statistics in the table are those from Dement and Finkelstein, both of which predict a relative risk of about 5.2, for an excess of 420% at 100 f/cc-yrs. It is obvious that the Dement and Finkelstein data predict enormously greater health risks from a given fibre exposure than do the other studies.

The coefficients and equation presented in Table 7.2 can be used to estimate the risk presented at the lower exposure levels experienced by our short-term, normally exposed or long-term, highly exposed workers. Under a 1 f/cc control limit a short-term, normally exposed worker would be exposed to 5 f/cc-yrs over his work life. The equation from Table 7.2 would predict an excess risk from lung cancer of less than 1% at this fibre level, with two exceptions: both the Dement and Finkelstein studies would predict

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<sup>44</sup>J. Corbett McDonald et al., "Dust Exposure and Mortality in Chrysotile Mining, 1910-75," *British Journal of Industrial Medicine* 37 (1980): 11-24; J. Corbett McDonald et al., "Mortality in the Chrysotile Asbestos Mines and Mills of Quebec," *Archives of Environmental Health* 22 (June 1971): 677-685; Vivian L. Henderson and Philip E. Enterline, "Asbestos Exposure: Factors Associated with Excess Cancer and Respiratory Disease Mortality," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 117-126; Julian Peto et al., "A Mortality Study Among Workers in an English Asbestos Factory," *British Journal of Industrial Medicine* 34 (1977): 169-173; Julian Peto, "Lung Cancer Mortality in Relation to Measured Dust Levels in an Asbestos Textile Factory," in *Biological Effects of Mineral Fibres*, vol. 2, ed. J.C. Wagner, IARC Scientific Publications, no. 30 (Lyon, France: International Agency for Research on Cancer, 1980), pp. 829-836; John M. Dement et al., "Estimates of Dose-Response for Respiratory Cancer Among Chrysotile Asbestos Workers," *Annals of Occupational Hygiene* 26:1-4 (1982): 869-887; Geoffrey Berry and Muriel L. Newhouse, "Mortality of Workers Manufacturing Friction Materials Using Asbestos," *British Journal of Industrial Medicine* 40:1 (February 1983): 1-7; and Murray M. Finkelstein, "Mortality Among Employees of an Ontario Asbestos-Cement Factory," Toronto, Ontario Ministry of Labour, February 1983, revised September 1983. (Mimeographed.) See also, Irving J. Selikoff, E. Cuyler Hammond, and Herbert Seidman, "Mortality Experience of Insulation Workers in the United States and Canada, 1943-1976," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 91-116.

Table 7.1  
Mortality Experience in Seven Epidemiological Studies

Result	J.C. McDonald* (Mining)			Enterline (Manufacturing)			Peto (Textiles)			Dement (Textiles)			Berry** (Friction Products)			Finkelstein*** (Asbestos-Cement)			Selikoff (Insulation)		
	O	E	RR§	O	E	RR	O	E	RR	O	E	RR	O	E	RR	O	E	RR	O	E	RR
a) Overall risks (≥ 20 years since first exposure)																					
(i) Lung cancer	230	184.5	1.25	63	23.3	2.70	22 (Hired ≤ 1950) 8 1.62 4.94 (Hired ≥ 1951)			23	5.7	4.04	143	139.5	1.03†	21	4.1	5.12	450	93.7	4.8
(ii) Gastrointestinal cancer	209	203	1.03	55	45.6	1.21	16	15.7	1.02	9	7.10	1.27††	103	107.2	0.96	8	2.8	2.83	93	53.2	1.8
(iii) Pleural mesothe- lioma deaths	10			5			7			0			8						61		
(iv) Peritoneal meso- thelioma deaths	0			0			0			1			0			8 (15 best evidence)			109		
(v) Fibrotic lung disease deaths	42			31			8 (Hired ≤ 1950) 0 (Hired ≥ 1951)			15††			Not mentioned			9 (non-malignant respiratory disease)			204	53.8	3.8
b) Lung cancer by dust/fibre level	mppcf-yrs < 10 10-99 100-299 300-599 ≥ 600	RR 1.0 1.0 1.2 1.8 2.9	mppcf-yrs < 125 125-249 250-499 500-749 ≥ 750	RR 1.98 1.80 3.28 4.50 7.78	f/cc-yrs < 27.4 27.5-109.5 109.6-273 ≥ 274	RR 2.23 3.57 9.78 15.53	mppcf-yrs < 9.1 9.1-36.5 36.5-91.3 91.3-182.6	f/cc-yrs < 30 30-75 75-105 105-150 ≥ 150	RR 2.31 6.15 12.08 9.0 2.69	f/cc-yrst 50 100 150	RR 1.03 1.06 1.09	f/cc-yrs < 30 30-75 75-105 105-150 ≥ 150	RR 2.31 6.15 12.08 9.0 2.69	f/cc-yrst 50 100 150	RR 1.03 1.06 1.09	f/cc-yrs < 30 30-75 75-105 105-150 ≥ 150	RR 2.31 6.15 12.08 9.0 2.69	f/cc-yrst 50 100 150	RR 1.03 1.06 1.09	f/cc-yrs < 30 30-75 75-105 105-150 ≥ 150	RR 2.31 6.15 12.08 9.0 2.69

Notes: \*These data are for the men only, not the entire cohort.  
The J.C. McDonald cohort included 10,939 men (3,291 dead), and the Berry cohort included 9,113 men (1,787 dead).  
\*\*Ten years since first exposure.  
\*\*\*Production workers only.  
§"O" means observed; "E" means expected; and "RR" means relative risk.  
†Simulated exposure.  
††Includes all deaths from first exposure.

Table 7.2  
Estimated Relative Risk Coefficients for Lung Cancer

	J.C. McDonald (Mining)	Enterline (Manufacturing)	Peto (Textiles)	Dement (Textiles)	Berry (Friction Products)	Finkelstein (Asbestos- Cement)	Selikoff (Insulation)
Coefficient Value C*	at 3 f/cc 0.000463 at 7 f/cc 0.000198	at 9.5 f/cc 0.000693	0.01	at 3 and 8 f/cc 0.0416	0.00058	0.042	0.0101
Estimated Risk	3 f/cc	7 f/cc					
25 f/cc - yrs	1.012	1.005	1.25	2.04	1.015	2.05	1.25
50 f/cc - yrs	1.023	1.010	1.5	3.08	1.029	3.1	1.50
75 f/cc - yrs	1.035	1.015	1.75	4.12	1.044	4.15	1.76
100 f/cc - yrs	1.046	1.020	2.0	5.16	1.058	5.2	2.01

**Note:** \*The coefficient "C" may be inserted in the equation  $RR = 1 + C \times FCC \times D$  to estimate the relative risk of lung cancer from exposure to an asbestos concentration of FCC for a duration of D years.

SOURCE: Appendix to Chapter 7, Table 8.

a 21% excess risk. We are faced, therefore, with epidemiological studies that differ by more than a factor of 100 in the amount of excess lung cancer risk that they predict from particular exposures to asbestos dust. The long-term, highly exposed worker would be exposed to 25 f/cc-yrs over his work life. Table 7.2 shows excess lung cancer risks at this exposure level of less than 2% for J.C. McDonald, Enterline, and Berry and 25% for Peto and Selikoff, with Dement predicting a 104% excess risk and Finkelstein, a 105% excess risk.

### (c) Absolute Risk and Projections

The Appendix to Chapter 7 estimates the magnitude of health effects arising from different exposure levels.<sup>45</sup> It estimates the risk of death and the number of person-years of life lost from death resulting from lung cancer and mesothelioma at several fibre levels, relying on seven epidemiological studies. The Selikoff study included no exposure data, so the dose-response relationship was calculated using exposure estimates derived indirectly by the U.S. Environmental Protection Agency (EPA) based on dust measurements in other places at other times. The Appendix calculates effects based on the dose-response relationship of each study, using a detailed calculation of the number of workers surviving to each age, a more detailed procedure than that used in Table 7.2. The model is one in which the lung cancer incidence is proportional to the intensity (f/cc) and duration of asbestos exposure, with a delay period of 10 years after onset of exposure.<sup>46</sup> The incidence of mesothelioma, using a very different model, is proportional to the intensity of exposure and is related to the fourth power of

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<sup>45</sup> See the Appendix to Chapter 7 of this Report.

<sup>46</sup> For details of the model, see the Appendix to Chapter 7. The essence of the model is that the number of excess deaths per year at age  $a$  in a cohort of size  $NOW$  first exposed to asbestos at age  $A$  is given by the following equation:

$$IE(a) = C * FCC * D * NOW * LU(a) * S(a) / S(A),$$

Where:

$IE(a)$  = number of excess lung cancer deaths per year at age  $a$  resulting from asbestos exposure beginning at age  $A$ ;

$C$  = a proportionality constant derived from epidemiological studies;

$FCC$  = average intensity of exposure to asbestos in f/cc;

$D$  = duration of exposure to asbestos;

$NOW$  = number of workers exposed;

$LU(a)$  = the age-, gender-, and smoking-specific death rate for lung cancer;

$S(a), S(A)$  = the cumulative probability of survival to ages  $(a)$  and  $(A)$  respectively.

both time since first exposure and duration of exposure.<sup>47</sup> The Appendix assumes a hypothetical workforce of 1,000 persons who would work for 10 years beginning at age 22 and simulates the number of deaths that would result from various fibre exposures. A 25-year duration of exposure is also considered. The results of these simulations are shown in Table 7.3. There is again a wide range of predicted mortalities, with the analysis based upon the Dement and the Finkelstein data showing the greatest risks and those based upon the J.C. McDonald and the Berry data showing the least. On average in this simulation, those who do die will lose an average of approximately 13 years of life. Thus, the deaths occur at a relatively late age, as one expects with cancer. The combined mortality is slightly less than proportional to the fibre level in all studies, so that reducing the fibre level from 2 to 1 f/cc divides the death rate almost in half, and reducing it to 0.5 f/cc divides it in half again. Unlike Table 7.2, Table 7.3 includes mesothelioma deaths. Although the Berry cohort experienced 8 deaths from mesothelioma, more than the number of excess lung cancer deaths, this simulation includes lung cancer only, because Berry attributed the mesothelioma deaths to crocidolite.

These calculations estimate the risk from a short-term, normal exposure for 5 f/cc-yrs, which is shown in the 10-year column and the 0.5 f/cc exposure levels. The J.C. McDonald, Enterline, and Berry data would predict asbestos-related cancer mortality rates of considerably less than one death per 1,000 exposed workers at this exposure level. The Selikoff and Peto data would predict between 6.2 and 8.2 asbestos-related cancer deaths per 1,000 exposed workers. The Dement data predict 16 deaths, while the Finkelstein data predict a staggering 82 deaths, over 8% of the workforce. The Finkelstein data reveal cancer risks hundreds of times greater than those of some other studies at a given measured asbestos fibre concentration. It is possible that the model used here has overestimated the mesothelioma deaths that may occur in the future, especially in the Finkelstein cohort with its high mesothelioma rate, because of the assumption that mesothelioma deaths will continue to rise rapidly as the cohort ages. This assumption cannot be tested until the passage of time reveals the actual disease incidence of this cohort. Even if the assumption is unfounded, the

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$$^{47}MI(a) = K*[T^4 - (T-D)^4]*FCC*NOW*S(a)/S(A),$$

Where:

MI(a) = number of mesothelioma deaths per year at age *a* in a cohort of size NOW resulting from asbestos exposure beginning at age A;

K = a proportionality constant derived from epidemiological studies;

T = time since first exposure = *a* - A;

D = duration of exposure to asbestos;

FCC = fibre intensity in f/cc;

NOW = number of workers exposed;

S(a), S(A) = cumulative probability of survival to ages (a) and (A) respectively.

**Table 7.3**  
**Estimated Lifetime Mesothelioma and Lung Cancer Mortality Rates**  
**per 1,000 Asbestos-Exposed Workers\***

<b>Epidemiological Study</b>	<b>Fibre Exposure Level</b>	<b>10-Year Exposure Mortality</b>	<b>Total Life-Years Lost</b>	<b>25-Year Exposure Mortality</b>
Selikoff (assumed historical exposure = 15 f/cc)	2.0	32	431	64
	1.0	16	217	32
	0.5	8.2	109	16
	0.2	3.3	44	6.6
Peto	2.0	25	321	52
	1.0	12	161	26
	0.5	6.2	81	13
	0.2	2.5	32	5.3
McDonald 1: (assuming 3 f/cc = 1 mppcf)	2.0	0.7	9	1.8
	1.0	0.4	4.5	0.9
	0.5	0.2	2.3	0.5
	0.2	0.1	0.9	0.2
McDonald 2: (assuming 7 f/cc = 1 mppcf)	2.0	0.3	3.9	0.8
	1.0	0.2	1.9	0.4
	0.5	0.1	1.0	0.2
	0.2	0.03	0.4	0.1
Dement	2.0	62	782	144
	1.0	32	398	76
	0.5	16	201	39
	0.2	6.5	81	16
Enterline	2.0	1.1	14	2.7
	1.0	0.5	6.7	1.4
	0.5	0.3	3.4	0.7
	0.2	0.1	1.4	0.3
Finkelstein	2.0	295	4,193	460
	1.0	159	2,208	260
	0.5	82	1,133	138
	0.2	34	461	57
Berry	2.0	0.9	11	2.3
	1.0	0.5	5.6	1.1
	0.5	0.2	2.8	0.6
	0.2	0.1	1.1	0.2

**Note:** \*Assumptions: Duration of exposure = 10 years; 25 years. Age at first exposure = 22 years.

**SOURCE:** Adapted from: Appendix to Chapter 7, Tables 10, 11.

Finkelstein data would predict overall mortality risks at least twice as great as the Dement study.

The lifetime long-term, high exposure risk for 25 f/cc-yrs of exposure may be read from the 25-year column and the 1 f/cc exposure levels. In this case, the J.C. McDonald, Enterline, and Berry data would predict asbestos-related cancer mortality rates of less than 2 deaths per 1,000 workers. The Selikoff and Peto data would predict between 26 and 32 asbestos-related cancer deaths per 1,000 workers. The Dement data predict 76 asbestos-related cancer deaths, almost 8% of the workforce; while the Finkelstein data predict 260 deaths, or over one-quarter of the workforce.

#### (d) OSHA Projections

Another estimate of the risk of cancer from asbestos exposure was made for OSHA by Han K. Kang and Kenneth Chu, called "Preliminary Risk Assessment for Asbestos." This report is still in draft form two years after it was first issued, but has recently been made public in the United States.<sup>48</sup> The authors reviewed five studies, adding the study by Herbert Seidman, Irving J. Selikoff, and E. Cuyler Hammond [hereafter the Seidman study] to those we have considered.<sup>49</sup> Their estimate of deaths is summarized in Table 7.4 for the exposure of 1,000 workers to 2.0, 0.5, or 0.1 f/cc for a 45-year work life. There is, however, reason to believe that the Kang and Chu mortality rates were overestimated in the case of the predictions based upon the Seidman study, which is Study #3 in Table 7.4. Kang and Chu estimated the exposure of the workers in the Seidman study based on dust measurements at other plants at other times to an average of

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<sup>48</sup>Han K. Kang and Kenneth Chu, "Preliminary Risk Assessment for Asbestos," draft report prepared for the U.S. Department of Labor, Occupational Safety and Health Administration, Washington, D.C., 8 December 1981. Reference to this risk assessment was made in the U.S. Court of Appeals during litigation on ethylene oxide. This case was reported in *Public Citizen Health Research Group, et al. v. Thorne G. Auchter, Assistant Secretary, Occupational Safety and Health Administration, et al.*, Appellants 702 F.2d 1150 (1983). While this Commission's Report was in press, the U.S. Occupational Safety and Health Administration published a quantitative risk assessment in connection with its notice of an Emergency Temporary Standard on November 4, 1983. See U.S., Department of Labor, Occupational Safety and Health Administration, "Occupational Exposure to Asbestos; Emergency Temporary Standard," 29 CFR Part 1910, 48 FR 51086-51140, 4 November 1983. This Emergency Temporary Standard was stayed by court order. Comparing the dose-response coefficients reported in Table 9 of that notice with those reported in the Appendix to the present chapter, we find that of 10 comparable coefficients, in 3 cases the OSHA coefficients are virtually identical to ours, in 4 cases the OSHA coefficients are within 50% of ours, and 2 coefficients differ by up to a factor of 2. One coefficient, that for the Enterline study, differs by considerably more because of differing assumptions about the conversion of particle counts to fibre concentrations.

<sup>49</sup>See Herbert Seidman, Irving J. Selikoff, and E. Cuyler Hammond, "Short-Term Asbestos Work Exposure and Long-Term Observation," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 61-89.

about 35 f/cc for brief periods of time up to 2 years. At the time of the study, this intense but brief exposure had caused excess cancer mortality of about 15% of the workforce. When Kang and Chu used this experience to predict the health effects of exposure to 2 f/cc for 45 years, they assumed that a short, intense exposure is equivalent to a longer, less intense exposure, a proposition which we have questioned in Chapter 5. They predicted that over half of the workers exposed to 2 f/cc for their working life would die of asbestos-related cancer. Yet studies such as that by E. Cuyler Hammond, Irving J. Selikoff, and Herbert Seidman [hereafter the Hammond study] of other populations exposed to asbestos insulation for much longer periods show far lower disease rates than this.<sup>50</sup> Because the Seidman study was based on intense, short-term exposures, we believe it is incorrect to use the Seidman results for assessing the risk from exposure to 2 f/cc or lower levels over a long period of time.

The other total risk estimates presented by Kang and Chu were greater than those of Daniels and Roberts in the Appendix to this chapter, primarily because Kang and Chu assumed a longer duration of exposure, and for some studies Kang and Chu used a different conversion rate between particles and fibres.

#### (e) Analysis of the Projections

Are the risk assessments made by Daniels and Roberts in the Appendix to this chapter and by Kang and Chu consistent or inconsistent? Kang and Chu differ in part because they assumed a longer duration of exposure. We can, however, use the models in the Appendix to calculate risks for exposures similar to those assumed by Kang and Chu. Inserting in the equations from Table 7.2 an exposure of 45 years at 0.5 f/cc or 22.5 f/cc-yr, one of the exposures used by Kang and Chu, and assuming that the average lung cancer risk for a non-asbestos exposed worker is 0.075, we can calculate the excess cancer mortality per 1,000 workers as shown in Table 7.5. The model of Table 7.3 can also be used to calculate risks for 0.5 f/cc for 45 years as shown in Table 7.5. As Table 7.5 shows, the three risk assessments produce very similar risks when similar exposures are assumed, for the studies covered by all analysts. For the J.C. McDonald study, the highest estimate of risk is virtually the same. The Dement estimates are also within 15% of each other. The Kang and Chu estimates based on Enterline are 2 or more times those of the Appendix to Chapter 7, which is entirely the result of different conversion rates between particles and fibres.

While we have shown that the risk assessment by Kang and Chu, except for their use of the Seidman study, is not inconsistent with the

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<sup>50</sup>E. Cuyler Hammond, Irving J. Selikoff, and Herbert Seidman, "Asbestos Exposure, Cigarette Smoking and Death Rates," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 473-490.

**Table 7.4**  
**OSHA Draft Cancer Risk Estimates**  
**(Lifetime Cancer Risk for 1,000 Workers After 45-Year Exposure)\***

Exposure Level	2 f/cc	0.5 f/cc	0.1 f/cc
<b>Excess lung cancer</b>			
Study #1**	8-43	2-11	0.4-2
2	253-260	71-75	14-15
3	467	145	32
4	70	18	3.6
5	3	0.75	0.2
<b>Excess total cancer</b>			
Study #1	13-70	3-18	1-4
2	***	***	***
3	632	208	48
4	128	34	7
5	***	***	***

**Notes:** \* All estimates based on linear dose-response model. Other models yield similar or lower estimates.

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Study #1 Vivian L. Henderson and Philip E. Enterline, "Asbestos Exposure: Factors Associated with Excess Cancer and Respiratory Disease Mortality," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 117-126. For Study #1, the low estimate assumed that 1 mppcf = 5 f/cc, while the high estimate assumed that 1 mppcf = 1 f/cc.

Study #2 John M. Dement et al., "Estimates of Dose-Response for Respiratory Cancer Among Chrysotile Asbestos Textile Workers," Doctoral dissertation, University of North Carolina, Chapel Hill, North Carolina, 1980. For Study #2, the assumed historic exposure is up to 91 mppcf.

Study #3 Herbert Seidman, Irving J. Selikoff, and E. Cuyler Hammond, "Short-Term Asbestos Work Exposure and Long-Term Observation," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 61-89. For Study #3, the assumed historic exposure is up to 52.5 mppcf-yrs.

Study #4 E. Cuyler Hammond, Irving J. Selikoff, and Herbert Seidman, "Asbestos Exposure, Cigarette Smoking and Death Rates," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 473-490. For Study #4, the assumed historic exposure is up to 15 f/cc.

Study #5 J. Corbett McDonald et al., "Dust Exposure and Mortality in Chrysotile Mining, 1910-75," *British Journal of Industrial Medicine* 37 (1980): 11-24. For Study #5, the assumed historic exposure is often over 300 mppcf-yrs.

\*\*\*Data not available.

**SOURCE:** Adapted from: Han K. Kang and Kenneth Chu, "Preliminary Risk Assessment for Asbestos," draft report prepared for the U.S. Department of Labor, Occupational Safety and Health Administration, Washington, D.C., 8 December 1981.

**Table 7.5**  
**Comparison of Risk Assessments**

Epidemiological Study	Projected Asbestos-Related Cancer Mortality per 1,000 Workers Exposed to 22.5 f/cc-yr		
	Derived from Table 7.3	Derived from Table 7.2	Kang and Chu
J.C. McDonald 1	0.76	0.75	
2	0.33	0.38	0.75
Dement	65	71	71-75
Enterline	1.1	1.2	2-11

Appendix to Chapter 7 for a given fibre exposure, we consider that the 45-year exposure used by Kang and Chu is not a representative basis for risk assessment. We indicate above that we believe that a 10-year exposure and a 25-year exposure can represent the vast majority of exposures faced by workers in Ontario. We will therefore use the risk estimates of Table 7.3 for the short-term, normal exposure and the long-term, high exposure as a basis for evaluating control limits.

What should be done with the disparate risks suggested by the various epidemiological studies? We could assume that all are measuring the same risk and combine them. The Appendix to Chapter 7 evaluates the methodology of these studies and concludes that all are reasonably robust, and that none of them can be rejected on methodological grounds. These studies represent attempts to estimate the actual relationship between asbestos exposure and disease, with each estimate subject to some uncertainty or error. No one estimate is necessarily correct, but all might be used together to derive a better estimate than any alone. The average risk of the Table 7.3 studies, weighted by the number of subjects in each cohort, is about 5 asbestos-related deaths per 1,000 workers at an exposure of 5 f/cc-yrs. In a weighted average, the large Selikoff, Berry, and J.C. McDonald studies exert a considerable influence on the result, diluting the high risk estimates from the Dement and Finkelstein data.

However, we believe that the studies are measuring different risks. In Chapter 5 we differentiate risks by fibre type. We conclude that historical exposures to crocidolite and amosite were associated with higher disease rates than exposure to chrysotile. We conclude that mesothelioma is generally associated with exposure to amosite or crocidolite, and rarely with exposure to chrysotile. We recognize that chrysotile creates less dust in general, and further conclude that it is less hazardous at a given measured fibre level. These differences arise in part because the toxicity of fibres depends on their dimensions, and at a given optical count of fibres longer than 5 microns, amosite and crocidolite dust clouds contain a higher proportion of the long, thin fibres that are most dangerous than does a chrysotile dust cloud. Therefore, we reject the use of studies of crocidolite and amosite exposure to predict hazards from exposure to chrysotile.

We also conclude in Chapter 5 that for a single fibre type such as chrysotile, the health risk depends upon the process causing fibre release. We conclude that a given measured fibre concentration in mining and in brake manufacturing causes far less disease than the same measured fibre level in textile spinning and weaving. Working with sprayed insulation and pipe and boiler insulation causes intermediate risk levels. These differences arise in part because the toxicity of fibres depends on their dimensions and because the airborne fibre size distribution differs among processes. Thus, we reject combining studies of these processes to yield a single dose-response relationship.

### (f) Summary of Projections by Fibre Type and Process

Our conclusion in Chapter 5 that fibre type and process may affect the risk to workers requires us to separate the studies discussed here for purposes of risk assessment. We will consider separately chrysotile atmospheres, and mixed atmospheres containing chrysotile and either amosite or crocidolite or all three. We will also separate mining, two general types of manufacturing, and other processes. In each case, we will identify the studies that we believe are relevant for risk assessment and determine the risk presented by exposure under whichever of the recently adopted Ontario control limits is applicable. The results are summarized in Table 7.6.

*Mining — Chrysotile* — In Ontario, natural deposits of asbestos appear to include only chrysotile, with no amosite or crocidolite.<sup>51</sup> This is true for asbestos mines and for other mines in which asbestos may appear as a contaminant. The J.C. McDonald study is the only study of the health effects of chrysotile miners. Therefore, we will use the J.C. McDonald study to estimate the risk from mining exposures to chrysotile in Ontario. The recently adopted Ontario control limit for chrysotile exposure is 1 f/cc. Table 7.6 shows that the short-term, normal exposure under this control limit yields a risk of 0.1 to 0.2 deaths per 1,000 workers; while a long-term, high exposure yields a risk of 0.4 to 0.9 deaths per 1,000 workers.

*Manufacturing — Chrysotile Only* — Ontario manufacturers of asbestos products today use, as an input, chrysotile fibres exclusively, to the best of our knowledge. However, not all manufacturing processes are alike. We will distinguish two general types of manufacturing processes for risk assessment purposes. In the first process, chrysotile fibres are mixed with binders and formed into a hard product such as a brake lining, gasket, or floor tile. In this process, little work is performed on the asbestos fibres before they are submerged in materials which will tend to trap these fibres. Subsequent work on the material, such as grinding, will tend to reduce fibre lengths, perhaps below the hazardous range.

The second type of process is one in which extensive work is performed on the fibres without encapsulating them in some other material. In a textile plant, for example, asbestos fibres are woven into yarn and then spun into cloth. Although in some plants today water is used to reduce fibre release, in this process, in general, there is considerable work on the fibre while it is in relatively free form. We will use a textile plant as a typical example of the second type of process.

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<sup>51</sup> For an analysis of natural deposits of magnesite, talc, and asbestos in Ontario, see Ulrich Kretschmar and Dianne Kretschmar, *Talc, Magnesite and Asbestos Deposits in the Kirkland Lake - Timmins Area, Districts of Timiskaming and Cochrane*, Ontario Geological Survey Open File Report 5391 (Toronto: Ontario Ministry of Natural Resources, 1982).

Table 7.6  
Risk Assessment by Process and Fibre Type  
Recent Ontario Control Limit

Process	Fibre Type	Study Used	Applicable Control Limit (f/cc)	Short-term, Normal Exposure*	Long-term, High Exposure**	Mortality Risk per 1,000 Workers at the Control Limit
Mining	Chrysotile	J.C. McDonald	1.0	0.1-0.2	0.4-0.9	
Manufacturing	Chrysotile	Berry	1.0	0.2	1.1	
a) General (friction products)						
b) Textiles						
Manufacturing	Mixed (crocidolite)	Dement Peto***	1.0	16	76	
		Enterline Peto***	1.0	6.2	26	
		Finkelstein	0.2	0.06	0.3	
		Selikoff	0.2	1.3	5.3	
Other (insulation work)	Mixed (amosite)		0.5	17	57	
				4.1	16	

Notes: \* Assuming a 10-year average duration of exposure at one-half the control limit.

\*\* Assuming a 25-year duration of exposure at the control limit.

\*\*\* There is uncertainty whether this textile plant used crocidolite as well as chrysotile.

SOURCE: Derived from Table 7.3.

The first type of process includes brake shoe manufacturing, which employs the vast majority of manufacturing workers exposed to asbestos in Ontario today. The Berry study of health effects at a brake manufacturing plant is therefore directly relevant to this sort of exposure. The Ontario control limit applicable to chrysotile manufacturing is 1 f/cc. Table 7.6 shows that the Berry study would predict 0.2 deaths per 1,000 workers for a short-term, normal exposure; and 1.1 for a long-term, high exposure.

The second type of manufacturing process is typified by a textile plant. Once again, the 1 f/cc control limit would apply. The Dement study of a chrysotile textile plant would predict 16 deaths per 1,000 exposed workers for a short-term, normal exposure; and 76 deaths for a long-term, high exposure.<sup>52</sup> The Peto study of a textile plant in the United Kingdom is the subject of some debate as to whether crocidolite was used in addition to chrysotile. If the Peto study should be treated as a pure chrysotile exposure, it would predict 6.2 deaths per 1,000 workers for a short-term, normal exposure; or 26 deaths for a long-term, high exposure.

Is this separation of processes, for purposes of risk assessment, inevitable or even plausible? It is plausible because the processes are very different. In a textile plant, the raw fibre is worked on in loose form in ways that could easily break fibre bundles into smaller bundles or individual fibres. In a brake plant, the rigid moulded brake lining is drilled and ground. Since the fibres are embedded in a hard material, such operations will tend to break fibres into *shorter* fibres as well as breaking them apart. This could easily lead to a higher proportion of short fibres, below the most toxic lengths. In this connection, Dr. Dement stated that "Compared with other operations using chrysotile asbestos, such as the friction and cement product industries, textile operations were found to have a substantially higher fraction of long-thin fibres which [Mearl F.] Stanton and others have implicated as important for development of respiratory cancer."<sup>53</sup>

The separation of processes is not only plausible, it is compelling because of the epidemiological studies. The risks derived from Dement are almost 100 times greater than those derived from Berry. It is extremely unlikely that such differences are the result of errors of methodology in the studies or chance variations in lung cancer mortality. If these results are accepted at face value, then *something* has caused different risks at these plants. In the absence of other explanations, we believe that the differences are caused by differences in the manufacturing process that yield, among other things, different fibre sizes.

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<sup>52</sup>The plant studied by Dr. Dement performed the following operations: preparation/waste recovery, carding, spinning, winding, twisting, and weaving. See Dement et al., "Estimates of Dose-Response for Respiratory Cancer Among Chrysotile Asbestos Textile Workers," p. 876.

<sup>53</sup>*Ibid.*, p. 883. (Discussion.)

*Manufacturing — Mixed Fibres* — In the past, Ontario manufacturing operations involving mixed fibres included the production of asbestos-cement pipe and the production of insulation products. While these processes no longer operate today, it is still important to predict the health risks that might occur if they were to resume. Dr. Enterline studied workers who produced asbestos-cement products, insulation, and textiles, and who were exposed to all three major types of asbestos. The relevant Ontario control limit would be 0.2 f/cc and the predicted mortality risk, less than 0.1 per 1,000 workers for a short-term, normal exposure, or 0.3 deaths for a long-term, high exposure. If the textile plant studied by Peto is regarded as including crocidolite, then it too is relevant for manufacturing with mixed fibres. At the 0.2 fibre control limit, 1.3 deaths for a short-term, normal exposure, or 5.3 deaths for a long-term, high exposure per 1,000 workers would be predicted. Finally, the Finkelstein study involved crocidolite and chrysotile exposure in the pipe plant. Applying the control limit of 0.2 f/cc, Table 7.6 shows that 17 deaths per 1,000 exposed workers might be anticipated from a short-term, normal exposure, or 57 deaths from a long-term, high exposure. We, therefore, have a considerable range of risk estimates for manufacturing operations in mixed fibre atmospheres.

*Other Work — Mixed Fibres* — A major category of work not so far covered is the installation and removal of asbestos-containing insulation in buildings and on pipes and boilers. The Selikoff study of insulation workers is directly relevant. Dr. Selikoff's workers were exposed to amosite as well as chrysotile, so the relevant Ontario control limit would be 0.5 f/cc. Table 7.6 shows that the risk at a 0.5 fibre control limit level would be 4.1 deaths per 1,000 workers for a short-term, normal exposure, and 16 deaths from a long-term, high exposure. In Chapter 9 we discuss the risk estimates produced by the Hammond study. If, as the U.S. EPA stated, the Hammond study found 59 excess deaths per 1,000 workers attributable to an exposure of, on average, 9 f/cc,<sup>54</sup> then exposure to an average of 0.5 f/cc would cause less than 2.5 deaths per 1,000 exposed workers.

Another form of exposure is field work on asbestos-cement products. No studies are available to shed any light on the risks from such work. An important question which we cannot resolve is whether there is any reason to expect that the risks from such work would be similar to those experienced in the manufacture of asbestos-cement products. As the Finkelstein study showed, the manufacturing risks are high indeed.

We have now established a basis for estimating the risk that may be expected in the primary exposures that Ontario workers may face in the

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<sup>54</sup>U.S., Environmental Protection Agency, Office of Toxic Substances, *Support Document for Proposed Rule on Friable Asbestos-Containing Materials in School Buildings: Health Effects and Magnitude of Exposure*, EPA 560/12-80-003 (Washington, D.C.: U.S. Environmental Protection Agency, October 1980), Table 17, p. 80.

future. It must be remembered that all of these estimates are subject to the considerable uncertainty inherent in the underlying epidemiological studies and the extrapolation of high exposure health experience to the effects of low exposures. We believe, however, that these estimates are the best that can be made with the available data. We will use these estimates in our derivation of the appropriate level for control limits later in this chapter. We return now to several subsidiary issues: the impact on asbestos-related cancer risks of worker turnover, worker age, and smoking.

### (g) Effects of Other Factors on Health Risks

*Worker Turnover* — The Appendix to this chapter explores the impact of worker turnover on the mortality rate from lung cancer and mesothelioma. This is of interest because of the Peto hypothesis that for mesothelioma incidence the duration of exposure is less important than the number of years since the first exposure to asbestos. Mr. Peto has argued, with growing support from others, including Dr. Finkelstein and Dr. Nicholson et al., that the intensity of earlier exposure is more important than the intensity of later exposure in determining mesothelioma disease rates.<sup>55</sup> He captured this in a model in which disease was determined by the intensity of exposure and the time since first exposure. In such a model, the level of exposure in later years is less important in determining disease rates. The results of the analysis in the Appendix to this chapter, using data from the studies listed in Table 7.3, are shown in Table 7.7. The third column in this table shows the total mortality in an industry where at any given time 1,000 employees are working, and where they are exposed to 1 f/cc, with a total of 20 years of activity in the industry. If each worker works only 4 years, then there would be five workforces employed during the 20-year period. The Peto data would predict 27 deaths resulting from this high turnover rate. If each worker stayed for 10 years, there would be two different workforces, and a total of 25 deaths. If a single group worked for 20 years, the death rate would drop to 22, a reduction of about 19%. The Peto hypothesis predicts that only mesothelioma deaths will be affected by worker turnover. The Dement data report virtually no mesothelioma deaths but many lung cancer deaths. Thus, changing worker turnover has a negligible impact on the

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<sup>55</sup>See, for example, Julian Peto, "Dose and Time Relationships for Lung Cancer and Mesothelioma in Relation to Smoking and Asbestos Exposure," in *Zur Beurteilung der Krebsgefahren durch Asbest* [Proceedings of Bundesgesundheitsamt Asbestos Symposium], Berlin: February 1982, bga Schriften, MMV Medizin Verlag München, in press, 1983; Julian Peto, "An Alternative Approach for the Risk Assessment of Asbestos in Schools," report to the U.S. Environmental Protection Agency, 6 April 1981. (Mimeographed.) See also, Finkelstein, "Mortality Among Employees of an Ontario Asbestos-Cement Factory"; and William J. Nicholson et al., "Cancer from Occupational Asbestos Exposure: Projections 1980-2000," in *Banbury Report 9: Quantification of Occupational Cancer*, eds. Richard Peto and Marvin Schneiderman ([Cold Spring Harbor, New York]: Cold Spring Harbor Laboratory, 1981), pp. 87-111.

overall mortality using the Dement data, as shown in Table 7.7. The Finkelstein data include a large number of mesothelioma deaths and produce a mortality reduction of 40% when turnover is reduced. If we accept Peto's model, then the mortality can be cut by up to 40% in situations where considerable mesothelioma is expected by reducing worker turnover to increase the average duration of employment from 4 to 20 years. However, no such effect will occur if that mortality arises only from lung cancer rather than mesothelioma.

*Age at First Exposure* — Would there be any reduction in the risk of cancer mortality from asbestos exposure if the age at first exposure were increased? Suppose that the age at first exposure were 52 rather than 22 years. If there is a long latency period for cancers, then the 52 year old worker is unlikely to develop cancer before dying of natural causes, so the asbestos-related cancer risk would be greatly reduced. In the Peto model, the lung cancer risk is a function of age, while mesothelioma depends upon time since first exposure. In this model, later first exposure reduces the mesothelioma risk, while the lung cancer risk is reduced much less or even increased very slightly. The Daniels and Roberts Appendix calculates that raising the age of first exposure from 22 to 52, using their version of the Peto model, yields a 40% reduction in the total cancer risk using the Selikoff data and a 9% reduction using the Dement data, in which the risk is almost entirely from lung cancer rather than mesothelioma. Thus, increasing the age of first exposure to asbestos will in general reduce the cancer risk, although the reduction *may* be small where there is no risk of mesothelioma.

*Smoking* — What is the impact of smoking patterns on the risk of lung cancer and mesothelioma for asbestos workers? We observe in Chapter 5 that there is a strong multiplicative interaction between smoking and lung cancer, with heavy smokers in one study experiencing a lung cancer risk perhaps 11 times as great as that of non-smokers for a given level of asbestos exposure. We also conclude that smoking has no effect on the risk of mesothelioma. Thus, if workplaces that exposed workers to asbestos fibres employed only non-smokers, rather than the substantial proportion of smokers that are currently found, the overall cancer risk could be substantially reduced, especially in situations where the risk of mesothelioma is relatively small. The Appendix to this chapter analyzes the impact of replacing a plant workforce of 50% smokers with one consisting entirely of non-smokers, using the Peto model. Applied to the Dement data, the mortality risk reduction is 77%, because of the predominance of lung cancer in the Dement cohort. Using the Peto data, in which there are roughly similar proportions of lung cancer and mesothelioma, the risk reduction is 44%. It is therefore clear that employing only non-smokers can greatly reduce cancer risks from asbestos exposure where mesothelioma is not a major source of that risk. This is of particular importance in Ontario where,

**Table 7.7**  
**The Predicted Effects of Decreasing Worker Turnover**  
**(2 f/cc; Age = 22)**

Duration of Employment	Data Used	Total Mortality in One Workforce	Number of Workforces (X) Over 20 Years	Mortality for X Workforces to Receive 20 Years' Exposure
4 Years	Peto	5.4	5	27
	Dement	12.9		65
	Finkelstein	78.1		390
10 Years	Peto	12.4	2	25
	Dement	31.8		64
	Finkelstein	159		317
20 Years	Peto	22	1	22
	Dement	62		62
	Finkelstein	236		236

SOURCE: Adapted from: Appendix to Chapter 7, Table 14 (excerpt).

because crocidolite is no longer used, the risk of mesothelioma is far below that of lung cancer.

## D. Current Fixed Workplace Asbestos Control Limits

Chapter 3 of this Report contains a detailed history of the regulation of worker exposure to asbestos fibres in Ontario, along with the relevant developments in the United States and the United Kingdom. As a background to our recommendations for control limits for such exposure, we present here a brief summary of the current status of the control limits in Ontario, other Canadian provinces, the United States, and the United Kingdom. Table 7.8 records the present numerical control limits in these jurisdictions.

In Ontario, the Regulation Respecting Asbestos, adopted in August 1982, set a control limit for a worker's time-weighted average exposure of 1 f/cc for chrysotile and all other forms of asbestos, except amosite which is subject to a 0.5 f/cc control limit, and crocidolite which is subject to a 0.2 f/cc control limit.<sup>56</sup> The TWA is to be calculated as the average exposure over a 40-hour week.<sup>57</sup> The short-term exposure limit, representing the maximum concentration to which a worker may be exposed for 15 minutes, is 5 times as great as the corresponding TWA control limit for each asbestos type.<sup>58</sup> In mixed asbestos fibre atmospheres, the control limit applied to all fibres is the one applicable to the most strictly regulated fibre type present.<sup>59</sup>

Most of the other Canadian provinces have tended to use the threshold limit values (TLVs) of the American Conference of Governmental Industrial Hygienists (ACGIH) as a basis for regulating asbestos. Thus, the present occupational standard in British Columbia, Alberta, New Brunswick, Nova Scotia, and Newfoundland is 2 f/cc for chrysotile, 0.5 f/cc for amosite and tremolite, and 0.2 f/cc for crocidolite.<sup>60</sup> Prince Edward Island seems not to have adopted a specific asbestos regulation. In Manitoba, a limit of 0.1 f/cc for all types of asbestos is apparently being considered.<sup>61</sup>

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<sup>56</sup> Regulation Respecting Asbestos, s. 4(1).

<sup>57</sup> See Schedule to Regulation Respecting Asbestos.

<sup>58</sup> Regulation Respecting Asbestos, s. 4(2).

<sup>59</sup> *Ibid.*, s. 4(3).

<sup>60</sup> British Columbia — Industrial Health and Safety Regulations, B.C. Reg. 585/77, as am. by B.C. Reg. 374/79; Alberta — General Accident Prevention Regulation, Alta. Reg. 267/76, s. 79; New Brunswick — Occupational Safety Code Regulations (N.B. Reg.) 80-82, s. 8(4); Nova Scotia — Occupational Health Regulations R.&R., S.N.S. 76, 1510, s. 4(1); Newfoundland — Occupational Health and Safety Regulations, Nfld. Reg. 140/79, s. 31(6).

<sup>61</sup> Telephone communication between Mr. Dennis Nikkel, Industrial Hygiene Section, Workplace Safety and Health Division, Department of the Environment and Workplace Safety and Health, Government of Manitoba and Royal Commission on Asbestos Staff.

**Table 7.8**  
**Summary of Asbestos Control Limits, 1983**  
 (All in f/cc. Membrane filter method used, except as noted.)

Jurisdiction	Duration of TWA	Fibre Type		
		Chrysotile and Others	Amosite	Crocidolite
Ontario	40	1	0.5	0.2
Quebec	Not specified	2 (all types) (also 0.2 mg/m <sup>3</sup> , all types)		
Majority of other Canadian provinces	8	2	0.5 (and tremolite)	0.2
U.S.A. (OSHA)	8	2 (all types)*		
United Kingdom	4	1	0.5	0.2 (banned)
ACGIH	8	2	0.5 (and tremolite)	0.2

**Note:** \*While this Commission's Report was in press, the U.S. Occupational Safety and Health Administration issued an Emergency Temporary Standard of 0.5 f/cc for all types of asbestos, which was subsequently stayed by court order. See U.S., Department of Labor, Occupational Safety and Health Administration, "Occupational Exposure to Asbestos; Emergency Temporary Standard," 29 CFR Part 1910, 48 FR 51086-51140, 4 November 1983.

Saskatchewan has banned the use of crocidolite in the workplace<sup>62</sup> and has a general requirement that hazardous dust be maintained below current ACGIH levels.<sup>63</sup> Saskatchewan attempts to achieve the best practicable means of control and claims to have enforced control measures even below levels of 0.02 f/cc, although it is not clear how air monitoring of such levels is achieved.<sup>64</sup>

In Quebec, there is a control limit set by regulation under *The Quebec Mining Act* for asbestos exposure to all types of asbestos of 2 f/cc longer than 5 microns.<sup>65</sup> However, it appears that this control limit is deemed to be met if a gravimetric measurement of asbestos dust in the air yields less than 0.2 milligrams per cubic metre of air.<sup>66</sup> In any event, the actual fibre count (as opposed to the mass measurement) may not exceed a short-term ceiling value of 5 f/cc in the air. The same limits apply to manufacturing.<sup>67</sup>

In the United States, the Occupational Safety and Health Administration adopted, in July of 1976, a control limit of 2 f/cc for all types of asbestos measured over an 8-hour TWA with a 10 f/cc ceiling level during one hour.<sup>68</sup> In 1976, the National Institute for Occupational Safety and Health recommended to OSHA an exposure limit of 0.1 f/cc, which has not been adopted. In the summer of 1983, OSHA was under pressure to reconsider and tighten the 2 f/cc control limit.

In 1979, the U.K. Advisory Committee on Asbestos recommended control limits of 0.2 f/cc over a 4-hour period for crocidolite, 0.5 f/cc for amosite, and 1.0 f/cc for chrysotile.<sup>69</sup> The Advisory Committee recommended that there should in addition be a requirement to reduce exposure to the minimum that is reasonably practicable.<sup>70</sup> In 1978, it had recommended a ban on the spraying of asbestos-containing insulation.<sup>71</sup> The Health and Safety Executive announced on August 27, 1982 that the Health

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<sup>62</sup> *The Occupational Health and Safety Act*, R.S.S. 1978, c. 0-1, s. 109, and Asbestos Regulations, Sask. Reg. 58/75, s. 2(2).

<sup>63</sup> Accident Prevention Regulations, Sask. Reg. 283/69, s. 16.02.

<sup>64</sup> RCA Transcript, Evidence of Mr. Robert Sass, 15 June 1982, Volume no. 40(A), p. 9.

<sup>65</sup> Regulation amending the Regulation respecting the safety of the workmen and sanitary conditions in mines and quarries, O.C. 2308-77 (1977) 109 *Gazette Officielle* II 3793; Q. Reg. 77-405.

<sup>66</sup> *Ibid.* One milligram is one million nanograms, so this standard equals 200,000 ng/m<sup>3</sup>.

<sup>67</sup> Regulation respecting the quality of the work environment, O.C. 3845-80 (1981) 113 *Gazette Officielle* II 87.

<sup>68</sup> 29 CFR 1910. 1001.

<sup>69</sup> U.K., Advisory Committee on Asbestos, *Asbestos — Volume I: Final Report of the Advisory Committee*, Recommendations 14, 17, and 15, pp. 74, 78, 77 respectively.

<sup>70</sup> *Ibid.*, Recommendation 10, p. 73.

<sup>71</sup> U.K., Advisory Committee on Asbestos, *Asbestos — Work on Thermal and Acoustic Insulation and Sprayed Coatings* (London: Her Majesty's Stationery Office, 1978); and U.K., Health and Safety Commission, *Consultative Document: Asbestos Insulation and Coating — Draft Regulations* (London: Her Majesty's Stationery Office, 1981), p. 3.

and Safety Commission had adopted the recommended control limits, to take effect January 1, 1983. The Commission also decided to prohibit the spraying of asbestos, to prohibit the use of asbestos in insulation, and to prohibit the import, use, and marketing of crocidolite and products containing it.<sup>72</sup>

In Europe, the Council of the European Communities is currently considering asbestos control limits. Each member country would be expected to adopt control limits equal to or more strict than any directive finally made by the Council. No control limits have yet been adopted; however, the limits that have been discussed are an 8-hour TWA of 1.0 f/cc for all types of asbestos other than crocidolite, and a more strict limit for crocidolite.

## E. Criteria for Setting Control Limits

What criteria should be used for determining the maximum asbestos fibre level to which workers may be exposed in Ontario? Labour organizations appearing before this Commission made various arguments that exposure to asbestos should be reduced as far as possible. The Labour Council of Metropolitan Toronto recommended that all "non-essential" uses of asbestos be phased out by June 1982, and that essential uses be defined as those for which there is no safe substitute available.<sup>73</sup> Where asbestos use continues, the exposure should be limited to the lowest amount measurable. In a written submission to this Commission, the United Steelworkers advocated reducing exposure to asbestos fibres to "an irreducible minimum."<sup>74</sup> The Ontario Federation of Labour (OFL) recommended that all non-essential uses of asbestos be phased out within one year, with all uses phased out as soon as safe substitutes are available, but no later than four years.<sup>75</sup> On the other hand, the OFL argued that substitutes should not be used unless proved safe, and that fibreglass has not been so proved.<sup>76</sup> Few

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<sup>72</sup>U.K., Health and Safety Executive, "New Safety Limits for Asbestos," *News Release*, 27 August 1982. In a copy of a telex to the British Embassy in Washington and dated 24 August 1983, sent by Mr. Cyril D. Burgess of the U.K. Health and Safety Executive to the Royal Commission on Asbestos, it was stated, *inter alia*, that the Health and Safety Commission had decided that: "1. Exposure limits for chrysotile to be reduced to 0.5 fibres per ml and for amosite to 0.2 fibres per ml effective from 1 August 1984. 2. A ban should be placed on the importation and use in manufacture of amosite and products containing it. Prohibition regulations should be brought forward for amosite and crocidolite to come into effect on 1 June 1984. . . ."

<sup>73</sup>Labour Council of Metropolitan Toronto, Written submission to the Royal Commission on Asbestos, #13, January 1981, p. 21.

<sup>74</sup>United Steelworkers of America, Written submission to the Royal Commission on Asbestos, #42, February 1981, p. 3.

<sup>75</sup>Ontario Federation of Labour, Written submission to the Royal Commission on Asbestos, #35, January 1981, p. 124.

<sup>76</sup>*Ibid.*, p. 78.

substitutes are likely to pass this rigorous test in the near future. While these positions fall short of demanding an immediate end to all uses of asbestos in Ontario, they do explicitly reject the notion of "acceptable risk" and the use of cost-benefit analysis to determine control limits.

A number of parties appearing before this Commission explicitly raised the issue of substitutes for asbestos, and we consider it clearly relevant to our terms of reference. Of course, it is quite impossible for us to assess the thousands of uses of asbestos and to form a judgement on whether a substitute with adequate performance characteristics is available at a reasonable price for each use. We have made such judgements in some cases, as when we endorse the ban on spraying asbestos-containing fireproofing in buildings (see Chapter 9); or when we recommend a ban on the sale of consumer products containing loose asbestos likely to release fibres during normal use or handling (see Chapter 11). In many cases, however, the evidence on the cost and performance of substitutes is mixed and does not lead to robust conclusions. Moreover, the evidence on the health effects of widely discussed substitutes for asbestos in manufacturing, which we review in Chapter 6, reveals few cases where an available substitute has been "proved safe," and provides no clear answer to the disturbing possibility that some substitutes may expose workers to fibres of dimensions similar to those we have found hazardous for asbestos. In Chapter 15 we discuss the responsibility of government to improve society's knowledge of the relative safety of asbestos substitutes through improved processes of hazard identification and assessment. For present regulatory purposes, we attach great importance to the fact that the hazardous nature of asbestos is known. We consider it better to regulate a known hazard rigorously than to compel the use of substitutes whose hazardous nature, being unknown, is not subject to regulation to a similar degree of rigour. Strict control limits can be set for asbestos exposure; current knowledge in the realm of hazard identification does not permit the setting of similarly strict limits for substitutes. If a firm can maintain worker exposure at the levels required by a rigorously enforced control limit, the alternative of forcing the firm to use a substitute is a leap into the unknown unless that substitute has been proved safe. If the control limit cannot be achieved, it is preferable to prohibit the firm from operating than to force it to use a substitute that has not been proved safe. Such prohibition is a powerful incentive to a firm to find a substitute that can indeed be proved safe and in our view is more effective than a blanket requirement that all firms using asbestos should search for asbestos substitutes.

We have reviewed a substantial body of literature and the reports prepared by researchers for this Commission, looking for guidance on an appropriate basis for setting occupational health standards. While this literature has offered a variety of ways of analyzing the problem, it has not provided a direct means of reaching quantitative conclusions. In their study for this Commission, Professor Carolyn J. Tuohy and Professor Michael J.

Trebilcock applied four frameworks for analyzing alternative policies for workplace control of asbestos: a scientific framework, an economic framework, a political framework, and an ethical framework.<sup>77</sup> They concluded that each of these frameworks can contribute to an evaluation of alternative policies, although they will frequently lead to results inconsistent with each other. Professor Tuohy and Professor Trebilcock emphasized that the process by which standards are set is important, and that the parties most directly affected by a standard should be centrally involved in designing that standard itself. They suggested that the standard-setting process inevitably involves a balancing of costs and benefits, whether this is done explicitly or implicitly. They were unable, however, to provide a formula that would define the "correct" standard for occupational exposure. In their study for this Commission, Professor G. Bruce Doern, Professor Michael Prince, and Mr. Garth McNaughton discussed the processes used for setting occupational and environmental standards.<sup>78</sup> They, too, derived conclusions about the appropriate process for standard-setting, but did not attempt to suggest the formula by which a standard can be selected. Other volumes have been written on risks, risk assessment, and decisions regarding risk. William D. Rowe developed an elaborate analytical framework for evaluating risks and assessing society's attitude towards those risks in *An Anatomy of Risk*.<sup>79</sup> The book is very informative, but the chapter called "Determination of Acceptable Levels of Societal Risks" contains some methodology which includes important value judgements that are either made by the author or left for the analyst to supply. While recourse to such a framework may lead to some understanding of the relative risks that exist in different situations, we do not see in this methodology any shortcut for arriving at an appropriate level of risk to be allowed in workplace situations. A book edited by Richard C. Schwing and Walter A. Alberts, Jr., called *Societal Risk Assessment*, contains many papers on risk assessment, the acceptability of risk, and many methods for calculating risk levels in different situations.<sup>80</sup> Cost-benefit analysis and decision analysis are discussed at length. Risks arising in various situations are presented and compared. Once again, however, we do not see here a single methodology that would lead us to a "correct" risk level or control limit for occupational exposure to asbestos.

Our conclusion is that setting a control limit requires first an assessment of the risk associated with different control limits. Once this risk

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<sup>77</sup> Carolyn J. Tuohy and Michael J. Trebilcock, *Policy Options in the Regulation of Asbestos-Related Health Hazards*, Royal Commission on Asbestos Study Series, no. 3 (Toronto: Royal Commission on Asbestos, 1982).

<sup>78</sup> G. Bruce Doern, Michael Prince, and Garth McNaughton, *Living with Contradictions: Health and Safety Regulation and Implementation in Ontario*, Royal Commission on Asbestos Study Series, no. 5 (Toronto: Royal Commission on Asbestos, 1982).

<sup>79</sup> William D. Rowe, *An Anatomy of Risk* (New York: John Wiley & Sons, 1979), chap. 18.

<sup>80</sup> Richard C. Schwing and Walter A. Alberts, Jr., eds., *Societal Risk Assessment* (New York: Plenum Press, 1980).

assessment has been completed, a variety of factors must be considered in selecting an appropriate control limit. We cannot escape making difficult judgements about risks that may be allowed in the workplace, nor can we conceal such judgements by the use of elaborate mathematical calculations.

There exist several approaches that could be applied to determining the appropriate control of worker exposure to asbestos. Exposures could be reduced: (i) until all health risks are eliminated; (ii) to the measurement limit, the level below which current measurement technology does not allow enforcement of standards; (iii) to the technological limit, the point below which current technology for controlling exposure does not permit further reductions; (iv) until the cost of further reductions exceeds the health benefits therefrom; or (v) until the remaining health risks are either not significant, or are acceptable. We will consider each of these approaches as a basis for controlling worker exposure to asbestos.

*Eliminating All Risks* — Desirable though it may be in principle, the idea of totally eliminating risk is not attainable in the real world. Since virtually every activity, in the workplace or the environment, involves some risk, it will always be necessary to approach any matter of health and safety in terms of relative risk, rather than in terms of absolutely eliminating risk. We conclude, based on the medical evidence discussed in Chapters 4 and 5, that the best conservative estimate of the dose-response relationship between asbestos exposure and lung cancer and mesothelioma is a straight line through the origin. This means that excess deaths due to cancer are not eliminated so long as exposure to asbestos fibres is not eliminated. At very low fibre levels, the health effect may be very small. Indeed, it may approach zero, without ever attaining it. Absolute freedom from risk is not attained in other aspects of occupational health and safety. Accordingly, we do not believe that absolute freedom from risk is an appropriate criterion for asbestos fibre control. The appropriate criterion must include a weighing of relative risks, discussed below.

*Measurement Limit* — We reject the concept of setting a control limit based upon measurement capability alone. In the first place, the definition of the measurement limit for a particular substance is an uncertain business in itself, with serious debate currently underway as to the lower limit of measurement capability. (See Chapter 7, Section B.) Even if agreement could be reached on the control limit that currently represents the lowest level that could reliably be measured, tying the control limit to measurement technology leaves workers and industry at the whim of uncertain technological change. Advances might not be made for a decade, or measurement capability might improve a hundredfold within a few years. The health consequences of a given exposure are not affected by measurement technology, nor are the costs of control. However, if it is concluded that the appropriate level of exposure is well below current measurement capabilities, then perhaps the substance should not be used at all. To tie the

control limit solely to measurement capability is to abrogate the responsibility for making a difficult decision; namely, to prohibit use of a substance that poses an unacceptable risk even when exposures are below the level of measurement capability.

*Best Technology* — For similar reasons, we reject the explicit setting of a control limit based solely upon the best available technology. The problem with this approach is that it leaves protection of the worker to the uncertain outcome of research and development in the technology of worker protection. We do not believe that responsible governments should abandon their decision-making responsibilities to the uncertain outcomes of engineering research and development. If the appropriate control limit cannot currently be achieved, then perhaps the substance should not be used at all. If, on the other hand, a satisfactory control limit does not require use of the most sophisticated available technology, unnecessary expense should be avoided.

Furthermore, a careful examination of the application of control limits which purport to require that the best technology be installed will reveal that in fact cost considerations are often taken into account. There are few occupational or environmental problems where further exposure reduction is not technologically achievable at some — perhaps astronomical — cost, in worker inconvenience, in money, or both. If one combines complete process enclosure with worker isolation and elaborate respiratory protection for maintenance workers, worker exposure levels to asbestos fibres could conceivably be reduced nearly to zero. We believe, however, that if a “best available technology” control limit were adopted, its implementation would not lead to near zero exposure, but rather to an exposure that was limited by the cost of more extensive controls. We think that the adoption of a best available technology approach would be deceptive because we believe that cost considerations would manage to insert themselves in the implementation of such a control limit.

*Cost-Benefit Analysis* — We do not accept the use of cost-benefit analysis as the sole means for identifying a specific control level. Submissions to this Commission have identified the severe limitations of cost-benefit analysis for yielding a single, unambiguous number representing the appropriate control level. Our discussion of control costs in Chapter 6 suggests substantial uncertainty about actual cost levels, and the discussion of health effects in Chapters 4 and 5, and in Section C of this chapter, suggests an enormous range of uncertainty in the possible health outcomes from various exposure levels. While a weighing of cost and benefit information may be useful in deliberations about the selection of an appropriate control level, it cannot identify a unique control level. Nor should cost-benefit analysis alone determine the control level even if enormous uncertainty did not exist, since factors which cannot be entered in a quantitative

form in a cost-benefit analysis should play an important role in reaching occupational health and safety judgements.

We believe that the concept of relative risk with the addition of some of the approaches just discussed constitutes a basis for controlling worker exposure to asbestos to acceptable levels. The concept of relative risk suggests that the significance of a risk can be determined by comparison with other risks that are faced by workers. If a risk is sufficiently small, compared to other risks faced by workers, it might be regarded as insignificant and hence not warranting further action to reduce the risk. We will conclude in the next section that the risks from asbestos-related disease faced by Ontario workers under the recently adopted asbestos control limits are significant; this requires in turn an assessment of whether these significant risks are acceptable.

One witness who appeared before this Commission suggested an absolute, rather than a relative, approach to determining the significance of a risk. Dr. Bailus Walker, Jr., after acknowledging the difficulty of determining when a risk becomes significant, suggested in an article he had written that a risk higher than 1 in 100 should be banned, a risk lower than 1 in 100,000 should be regarded as trivial, and a risk between these two levels should be the subject of public education warnings and efforts at reduction.<sup>81</sup> The implication is that a risk of cancer death of 1 in 100,000 is an insignificant risk, while a risk of 1 in 100 is significant, in fact so significant that it is unacceptable. Dr. Walker was not clear, however, on where between these widely separated points the insignificant becomes significant, nor on whether a risk of 1 in 100 refers to the probability of death in one year or in a lifetime. We are not convinced that such measures of absolute risk are helpful in formulating occupational health policy.

The acceptability of a risk depends upon a social value judgement made by the affected parties or by the legislature or by society as a whole. Numerous significant risks have been judged acceptable by the individuals who face them, the government agencies that regulate them, and society as a whole. Thus, while the risk of fatal accidents in mining is significant, that risk has been found acceptable in that the mining industry continues to operate; it has not been shut down by government nor by its own workers because of the risks faced by miners. To be sure, the acceptance of this risk is conditional. It is conditional on the continuation of efforts to reduce the

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<sup>81</sup>Bailus Walker, Jr., "Occupational Cancer," *Journal of Environmental Health* 44:4 (January/February 1982): 179.

risk. This is one reason for the frequency and thoroughness of investigations into mine safety.<sup>82</sup>

In assessing the acceptability of a risk, we will compare the risks caused by an asbestos exposure to the risks faced by workers from other sources, principally the risk of accidents. When a disease risk is below the accident risk, then it may (but need not) be considered acceptable. When the disease risk exceeds the accident risk, then it approaches the range of being not acceptable. Within this range, other factors may also be considered in assessing acceptability.

In defining significant and acceptable risk, we have referred to a comparison with other workplace risks. Would it be appropriate to consider non-workplace risks as well? Many studies have compared the risk of fatal injury in a wide variety of activities, and have compared the cost of additional life saving in those activities. Such studies show that a number of sporting activities are far more hazardous than most work activities. These facts are used to argue that individuals willingly face considerable risks, and that it is extravagant to be so protective in the workplace. The counter-argument is that there is a difference between voluntary assumption of risk in personal activities and the exposure to risk in a job which, once career and place-of-employment decisions have been made, is largely involuntary. We believe that it is not productive to compare risks in widely divergent types of activities because of the difficulty of interpreting the factors that influence those different choices. Furthermore, the risks that are allowed in different activities vary enormously. We are reluctant to spend small amounts to reduce the highway death toll further, yet we spend large amounts of money to avoid occupational health risks. For example, John D. Graham and James W. Vaupel found that in the United States the median cost per life saved in various programmes was \$64,000 in motor vehicles and highways; \$102,000 in medical programmes; \$50,000 in consumer protection; \$2.6 million in environmental protection; and \$12.1 million in occupational health and safety programmes.<sup>83</sup> Not all the programmes analyzed have in fact been adopted by the U.S. government, but these figures indicate the range of costs associated with saving a life in various programmes in the United States. Thus, a comparison of the risks faced by a variety of groups in a variety of activities provides little guidance as to whether workplace risks are significant or acceptable. We will, therefore, compare asbestos-related risks only with other workplace risks.

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<sup>82</sup>See Ontario, *Report of the Royal Commission on the Health and Safety of Workers in Mines* (Ham Report), James M. Ham, Commissioner (Toronto: Ministry of the Attorney General, 1976); and Canada/Ontario, *The Report of the Joint Federal-Provincial Inquiry Commission into Safety in Mines and Mining Plants in Ontario: Towards Safe Production* (Burkett Report), Kevin M. Burkett, Chairman, 2 vols. (Toronto: April 1981).

<sup>83</sup>John D. Graham and James W. Vaupel, "Value of a Life: What Difference Does it Make?" *Risk Analysis* 1:1 (March 1981): 91.

While we believe that some risks that are significant may be acceptable, we believe that some significant risks may be so substantial that they are unacceptable. It goes without saying that the illness and death that have been caused by high asbestos exposures in the past in Ontario and elsewhere in the world must be judged completely unacceptable. Well below this, the level of significant risk that is unacceptable depends in part upon the type of risk and the perception of the risk. Jobs involving risks to safety that are obvious to the worker, and which the worker can evaluate and judge intelligently, may be allowed to continue at a higher level of risk than jobs in which the risk is not obvious. In the former case, it can at least be argued that the worker can make an informed choice about accepting the risks with the job and can take action to reduce those risks when on the job. Thus, a higher risk of fatal accidents has been tolerated in mining and construction than in manufacturing, in part because the accident risks in mining and construction are well known to the workers. Workers who enter manufacturing do not, in general, expect nor accept such high accident risks. More important, the risk of disease is neither visible nor obvious to workers. The risk of long-latency diseases such as asbestos-related cancer, when caused by dust levels that are hardly visible to the naked eye, as are current asbestos exposures in manufacturing, would be completely unknown to a worker unless he were specifically informed of the risk. If the worker cannot be expected to know about the risk or form an intelligent opinion about the severity or magnitude of the risk, then the socially acceptable risk level must be considerably lower than if the risk is obvious.

When the risk of disease is significant, the determination of the acceptable risk level must depend upon whether the risk is known to, and understood by, the worker, the health effects of alternative exposure levels, the technology available for controlling that exposure, and the cost of control. If real reductions in the health risk can be achieved at a reasonable cost, then those reductions should be made mandatory by lowering the control limit.

If the risk of disease becomes insignificant, there is little gain from further control. If the cost of control is already high, then imposing still more strict control limits might not only cause costly short-term dislocations for both labour and industry, but might alternatively divert resources from attacking other health and safety problems in the plant where the improvement in worker health might be greater.

## **F. Recommendations on Workers' Exposure**

How do the Ministry of Labour's recently adopted control limits fare under our criteria? Table 7.9 repeats the estimated risk of mortality from cancer predicted by the studies presented in Table 7.6 in Section C above for short-term, normal exposure (10 years' duration at one-half the

control limit) and for long-term, high exposure (25 years' duration at the control limit). We may compare these estimated asbestos-related mortality rates to other risks faced by workers to determine whether the risk is significant. We will consider each process separately. It must be remembered that considerable uncertainty is associated with all of the estimated risks, so each number discussed should be regarded as representing a range of possible risks.

How do these risks compare with other occupational risks? *The Report of the Joint Federal-Provincial Inquiry Commission into Safety in Mines and Mining Plants in Ontario* showed accident fatality rates per million person-hours of work equal to 0.038 in manufacturing, 0.160 in construction, and 0.516 in mining.<sup>84</sup> If a workforce of 1,000 workers were employed for 10 years, working 2,000 hours per year, they would work a total of 20 million person-hours. Twenty-five years of work would yield 50 million person-hours. The number of hours of work may be multiplied by the accident fatality rate to determine the approximate fatal accident risk for such a workforce. Twenty million person-hours of work in manufacturing would result in an average accident risk of about 0.8 fatalities for 1,000 workers employed for 10 years. The same amount of work in construction would result in an average fatal accident risk of 3.2, and in mining, a risk of 10.3. The corresponding risks for 50 million hours of work would be 1.9, 8.0, and 25.8. These accident risks are presented at the bottom of Table 7.9. We do not have data on the person-years of life lost for these sectors, but accident deaths tend to occur at an early age, while asbestos deaths occur at a later age because of latency. Thus, perhaps 4 times as many person-years of life might be lost in accident deaths as in the same number of asbestos-related cancer deaths. While this is a statistical fact, we will rely primarily on the raw mortality data, rather than losses in person-years of life in making our risk comparisons.

We stated in Section E above that a risk was insignificant only if it was far below the level of other risks faced by workers generally. Under the 1982 Ontario control limits, the lowest risk for any process or fibre type is 0.06 possible deaths per 1,000 workers exposed for 10 years, while the manufacturing accident rate is approximately 0.8. (See Table 7.9.) We believe that this difference is not so great as to render the mortality risk from asbestos exposure insignificant. We will therefore consider, for each process, whether this significant disease risk is acceptable.

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<sup>84</sup>Canada/Ontario, *The Report of the Joint Federal-Provincial Inquiry Commission into Safety in Mines and Mining Plants in Ontario: Towards Safe Production*, vol. 2: *Statistics and Research Reports*, p. 15.

Table 7.9  
Risk Assessment by Process and Fibre Type  
Recent Ontario Control Limits

Process	Fibre Type	Study Used	Applicable Control Limit (f/cc)	Short-term, Normal Exposure*	Long-term, High Exposure**	Mortality Risk per 1,000 Workers at the Control Limit
Mining	Chrysotile	J.C. McDonald	1.0	0.1-0.2	0.4-0.9	
Manufacturing	Chrysotile	Berry	1.0	0.2	1.1	
a) General (friction products)						
b) Textiles						
		Dement Peto***	1.0	16	76	
			1.0	6.2	26	
Manufacturing	Mixed (crocidolite)	Enterline Peto***	0.2	0.06	0.3	
			0.2	1.3	5.3	
		Finkelstein	0.2	17	57	
Insulation work	Mixed (amosite)	Selikoff	0.5	4.1	16	
<b>Workplace accident risks</b>						
	Manufacturing accidents (0.038 x 20, 50)			10 Years	25 Years	
	Construction accidents (0.16 x 20, 50)			0.8	1.9	
	Mining Accidents (0.516 x 20, 50)			3.2	8.0	
				10.3	25.8	

Notes: \* Assuming a 10-year average duration of exposure at one-half the control limit.

\*\* Assuming a 25-year duration of exposure at the control limit.

\*\*\* There is uncertainty whether this textile plant used crocidolite as well as chrysotile.

SOURCE: Asbestos risks derived from Table 7.6. Accident risks derived from Canada/Ontario, *The Report of the Joint Federal-Provincial Inquiry Commission into Safety in Mines and Mining Plants in Ontario: Towards Safe Production* (Burkett Report), Kevin M. Burkett, Chairman, vol. 2: *Statistics and Research Reports* (Toronto: April 1981), p. 15.

## F.1 Mining

In asbestos mining, we estimate that the short-term, normally exposed worker faces an asbestos-related mortality risk of 0.1 to 0.2 per 1,000 workers, while the long-term, highly exposed worker faces a mortality risk of 0.4 to 0.9 per 1,000 workers. Even the highly exposed worker's risk is only 4% of the risk of accidental death in mining, while the normally exposed worker's risk is 1 to 2%. The mining worker's asbestos-related mortality risk is even below the accidental mortality risk in manufacturing.

Which comparison is relevant for determining the acceptability of this disease risk? While miners clearly accept higher risks of accidental death than do workers in manufacturing, we see no reason to believe that this acceptance extends to non-obvious and long-delayed disease risks. Although the risk of asbestos-related disease mortality in mining is small compared to the risk of accidental death in mining, it is not small when compared to the risk of accidental death in manufacturing. We are uneasy about adopting the high mining accident rate as a standard of comparison for evaluating health risks. We choose the risk of accidents in manufacturing as the relevant basis of comparison for determining the acceptability of health risks in mining.

Is this significant health risk acceptable? We find that this health risk falls well within the range of occupational health risks that have been found acceptable by society. This risk is a small proportion of the risk of accidental death in mining, and is below the risk of accidental death in manufacturing. (See Table 7.9.) We, therefore, endorse the application of the 1 f/cc chrysotile control limit to the mining industry, as is presently provided in the Regulation Respecting Asbestos.<sup>85</sup> Our finding of acceptability is, however, contingent upon workers being aware of the nature and magnitude of the risk of asbestos disease posed by their exposure. No worker should be exposed to a significant risk without his knowledge.

## F.2 Chrysotile Manufacturing

### (a) General

With respect to general chrysotile manufacturing processes, where the chrysotile is quickly encapsulated, as exemplified by friction products manufacturing, we estimate that the mortality risk faced by the short-term, normally exposed worker is 0.2 deaths per 1,000 workers, while the risk to the long-term, highly exposed worker is about 1.1 per 1,000 exposed workers. This may be compared to risks from accidental deaths in

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<sup>85</sup>Regulation Respecting Asbestos, s. 4(1). See also, Chapter 3, note 85 for amplification.

manufacturing of 0.8 to 1.9 deaths per 1,000 workers, although the asbestos-related deaths occur at a far older age on average than those from accidents.

Is this significant risk acceptable? We find that this health risk falls well within the range of occupational health risks that have been found acceptable by society. The risk is on average less than that from accidental death in manufacturing, and the number of life-years lost is substantially less. The 1,200 or so Ontario manufacturing workers now exposed to asbestos could work for 10 years and there would be only a one in four chance of a single premature death among the 1,200 from this exposure. The 1 f/cc chrysotile control limit reduced the allowable exposure of workers in Ontario by 50% compared with the guideline which previously existed and to 10% or less of the exposures experienced during the 1950s. We have seen no evidence of high disease rates from chrysotile asbestos manufacturing in Ontario in the past, and the recently adopted control limit will greatly reduce such disease risks as existed. Our finding of acceptability is, however, contingent upon certain conditions being met:

- (i) if compliance with the control limit is such that the exposure of the average worker is significantly less than the control limit;
- (ii) if workers are aware of the nature and magnitude of the health risks posed by this exposure — no worker should be exposed to a significant risk without his knowledge; and
- (iii) if the Regulation Respecting Asbestos is enforced so that plants which can achieve exposure levels well below the control limit will do so.

We observe that the Regulation Respecting Asbestos made under the *Occupational Health and Safety Act* in August of 1982, in section 4(1), not only states numerical exposure limits for the three major types of asbestos, but precedes the statement of these limits with the requirement “. . . that the time-weighted average exposure of a worker to airborne asbestos is reduced to the lowest practical level and in any case shall not exceed. . . .” We interpret “the lowest practical level” to be a requirement that employers reduce exposures below the numerical control limit wherever this is technologically and economically reasonable. The implementation of “the lowest practical level” is discussed further in Chapter 8 of this Report.

### **(b) Textile Spinning and Weaving**

Next we consider manufacturing of chrysotile that is not encapsulated, represented specifically by the textile spinning and weaving industry. The estimated mortality risks indicated in Table 7.9 are 6.2 to 16 per 1,000 workers for the short-term, normal exposure, and 26 to 76 per 1,000 workers for the long-term, highly exposed worker under the recently adopted Ontario control limit. Such risks are clearly substantial, when com-

pared to the accidental death risk in manufacturing of 0.8 to 1.9 per 1,000 workers. These risks are even greater than the risk of death from accidents in mining. We find that this health risk falls beyond the range of occupational health risks that have been found acceptable by society. The normally exposed worker would be exposed to cancer risks more than 10 times greater than the risk of accidental death, and the highly exposed worker would face risks that might be 25 times greater than the accidental death risk. We do not believe that workers in Ontario should be asked to accept such substantial risks. We are not convinced that an information programme for workers could effectively communicate to them the magnitude of the long-term health risks they face, so that they could knowingly accept the risk.

At the present time, there are no substantial textile manufacturing operations in the province of Ontario. There is some weaving of asbestos packings from yarn spun outside the province, but here the yarn is generally coated with liquids before being woven. There is also some manufacture of textile products from cloth woven outside the province. However, there is the possibility that at some time in the future a textile spinning and weaving plant might be constructed in Ontario to operate under the 1 f/cc control limit. Having concluded that the risks involved in such textile operations are not acceptable, we believe that the Ministry of Labour should be in a position to prohibit the operation of such a plant unless it was assured that the health risks faced by workers were acceptable. Such assurance might arise if the risks were lowered by a factor of 25, so that they approached the same range as those of other chrysotile manufacturing. This might be achieved by a control limit for textile plants of 0.04 f/cc or by a control limit of 0.1 f/cc combined with a commitment to employ only non-smoking workers. However, at the present time, the standard workplace measurement method would be inadequate to enforce exposure levels below 0.1 f/cc. Alternatively, such assurance might arise if subsequent studies of chrysotile textile plants were to demonstrate that the Dement study has seriously overestimated the risks and that the true risk is considerably less. In light of these considerations, we recommend that:

*7.11 The Government of Ontario should adopt regulations that would prohibit the operation of asbestos textile spinning and weaving plants in Ontario without the approval of the Ministry of Labour. This approval should be granted only if the Ministry is satisfied that the health risks faced by workers in the plant are far lower than the unacceptable risks estimated in this Report.*

### **(c) Asbestos-Cement Production**

When we come to asbestos manufacturing involving mixed exposures, we shall recommend that the use of crocidolite and amosite be prohibited and thus in effect ban the manufacture of asbestos-cement pipe when chry-

sotile is mixed with either amosite or crocidolite. There remains the question of whether asbestos-cement manufacturing using chrysotile only should be regulated in the same manner as general chrysotile manufacturing or should be treated as a special case. The tragic health experience at the Scarborough Johns-Manville plant was one that involved exposure to crocidolite. Can it be, however, that this experience can also be attributed to peculiarities associated with the pipe manufacturing process, independent of the type of fibre used? The studies of asbestos-cement manufacturing without crocidolite suggest that the answer to this question is negative. The Weill study of New Orleans asbestos-cement plants discovered no excess risk of respiratory malignancy among those workers not exposed to crocidolite, while workers with crocidolite exposure suffered elevated health risks.<sup>86</sup> The Thomas study of Cardiff asbestos-cement manufacturing workers not exposed to crocidolite showed low excess risks of respiratory malignancy.<sup>87</sup> (See Chapter 5, Section B.) The Enterline study of Manville workers revealed a low excess risk of lung cancer for the entire cohort, which is the basis for the Enterline data in Table 7.9 and in Table 7.3.<sup>88</sup> Notably, however, the portion of the cohort exposed only to chrysotile in asbestos-cement operations experienced a lung cancer risk lower than that of the cohort as a whole, while those exposed to crocidolite in asbestos-cement production experienced excess lung cancer risks twice those of the cohort as a whole.<sup>89</sup> While the Appendix to Chapter 7 does not separately analyze the groups of workers exposed to different fibre types in the Enterline cohort, we can interpret its analysis of the cohort as a whole as an overestimate of the risk faced by the chrysotile-only asbestos-cement workers. Table 7.3 shows mortality risks for the Enterline data of 0.3 for the short-term, normally exposed worker under a 1.0 f/cc control limit, and of 1.4 for the long-term, highly exposed worker. These risks are close to the risks in Table 7.9 for friction products, which we determined fall within the range of societal acceptability. We find on the available evidence that the health risks from asbestos-cement manufacturing with chrysotile only are roughly similar in magnitude to those from friction products manufacturing. We, therefore, endorse treating asbestos-cement product manufacturing with chrysotile only as general chrysotile manufacturing and thus subject to the 1 f/cc control limit.

What about chrysotile-using manufacturers other than friction product, asbestos-cement, and textile spinning and weaving plants? We endorse

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<sup>86</sup>Hans Weill, Janet Hughes, and Carmel Waggenpack, "Influence of Dose and Fiber Type on Respiratory Malignancy Risk in Asbestos Cement Manufacturing," *American Review of Respiratory Disease* 120:2 (August 1979): 345-354.

<sup>87</sup>H.F. Thomas et al., "Further Follow-up Study of Workers from an Asbestos Cement Factory," *British Journal of Industrial Medicine* 39 (1982): 273-276.

<sup>88</sup>Henderson and Enterline, "Asbestos Exposure: Factors Associated with Excess Cancer and Respiratory Disease Mortality."

<sup>89</sup>*Ibid.*, p. 122.

regulation by fibre type and process because we believe that these are reasonable proxies for those factors that influence the toxicity of respirable asbestos fibres: their size and perhaps surface chemistry. Because medical science does not now tell us precisely what it is that makes some exposures to asbestos more hazardous than others, we must rely on the few studies that have differentiated risks. Reviewing the list of other manufacturing operations in Ontario, we find mostly operations in which raw asbestos is mixed with other materials, usually liquids, and then worked on in some fashion. (See Chapter 6.) These operations seem more like friction products manufacturing than like textile spinning and weaving from the viewpoint of what is done with the fibres. In the absence of evidence to the contrary, we will presume that the health effects of these general chrysotile manufacturing operations are reasonably well represented by the risk assessments based on friction products, rather than by assessments based on textile spinning and weaving. We are somewhat reassured in this presumption by the fact that the claims data of the Workers' Compensation Board do not reveal alarming claims records from individual chrysotile manufacturing firms in Ontario. We, therefore, endorse the application of the 1982 Ontario control limit of 1 f/cc for chrysotile to all chrysotile manufacturing operations except textile spinning and weaving.

### **F.3 Manufacturing — Mixed Exposures**

#### **(a) Crocidolite**

We now consider manufacturing of asbestos products using asbestos fibres other than chrysotile. The estimated health risk faced by the short-term, normally exposed worker, at the recently adopted Ontario control limit of 0.2 f/cc for crocidolite, as shown in Table 7.9, ranges from well below the accidental death rate in manufacturing, to the 17 deaths per 1,000 workers predicted from the Finkelstein study of workers exposed to chrysotile and crocidolite in asbestos-cement pipe manufacturing in Scarborough. Under the 0.2 f/cc control limit, the long-term, highly exposed worker would face risks ranging from 0.3 to 57 per 1,000 workers.

Are these significant risks acceptable? The risks projected by Enterline are acceptable, given our conclusion regarding chrysotile manufacturing above, but the Enterline study was heavily weighted by workers exposed to chrysotile only. The crocidolite-exposed workers experienced excess lung cancer risks more than double those reflected in the data in Table 7.9. (See Chapter 5, Section B.) The risks projected by Finkelstein are clearly unacceptable. The risks projected by Peto are on the borderline of acceptability. We do not have to decide if the Peto risks are acceptable because our recommendation regarding textile plants, which considered the Dement study as well, would require lower control limits than dictated by the Peto study alone.

Another assessment of the risks of exposure to crocidolite in manufacturing may be made by comparing the disease experience of the asbestos workers at the Johns-Manville asbestos-cement pipe plant with that of workers in other environments thought to cause risks of workplace disease, and particularly cancers. Dr. Murray M. Finkelstein of the Ministry of Labour has studied the Johns-Manville workers and has compared their disease rates with those of workers at Falconbridge and Inco.<sup>90</sup> Table 7.10 shows the mortality of workers in five situations from all malignancies and from lung cancer. The Inco sinter plant workers experienced an excess mortality from all malignancies of 81%, while the asbestos-exposed Johns-Manville workers experienced an excess mortality of 200%. Considering lung cancer alone, the Inco sinter plant workers experienced an excess mortality of 250%, while the Johns-Manville asbestos-exposed workers had an excess risk of lung cancer of 380%. Thus, the experience of Johns-Manville pipe plant workers appears worse than that of workers where other major occupational disease problems have been found in this province.

The tragic health experience of those who worked in the Johns-Manville pipe plant is not unusual for workplaces where crocidolite is used. Other studies, discussed in Chapter 5, have shown that high disease rates have been recorded whenever the health of workers exposed to crocidolite has been studied. The Weill study of New Orleans asbestos-cement plants revealed no excess risk of respiratory malignancy among those workers not exposed to crocidolite, while those workers exposed to crocidolite faced significantly higher disease rates.<sup>91</sup> (See Chapter 5.) These high disease rates may result partly from the high dust concentrations raised by working with crocidolite, but they also occur because, as we conclude in Chapter 5, at comparable airborne fibre concentrations measured by optical methods, the hazard presented by crocidolite is greater than that presented by chrysotile. Since we do not have formal dose-response equations for the other crocidolite studies, we will rely on the Finkelstein study, which is based on local Ontario conditions, to reflect the general risk of working with crocidolite. If this introduces any error, it is to overestimate the risk of crocidolite exposure.

The Finkelstein data show that extremely low exposures would be required to reduce the health risks of working with crocidolite to a level comparable to the risks from working with chrysotile. For example, a control limit of 0.02 f/cc for crocidolite, 1/10 the current control limit, would yield risks of 1.7 for the short-term, normally exposed worker, and 5.7 for the long-term, highly exposed worker. This implies that at a given exposure level crocidolite may be more than 300 times as hazardous as chrysotile in

<sup>90</sup>Murray M. Finkelstein, "Comparison of the Mortality Experience Among Employees of Inco and Falconbridge and Johns-Manville," Toronto, October 1982. (Mimeographed.)

<sup>91</sup>Weill, Hughes, and Waggenpack, "Influence of Dose and Fiber Type on Respiratory Malignancy Risk in Asbestos Cement Manufacturing."

**Table 7.10**  
**Cancer Mortality in Selected Ontario Workplaces**

Workplace	Excess Risk (%)	
	All Malignancies	Lung Cancer
INCO		
Non-sinter	-2%	5%
Sinter	81%	250%
Falconbridge	1%	47%
Johns-Manville		
Non-asbestos	33%	0
Asbestos-exposed	200%	380%

SOURCE: Summary by Dr. Murray M. Finkelstein of the results of his own studies of Johns-Manville's Scarborough asbestos-cement workers and of the JOHC-INCO Mortality Study and the Falconbridge Mortality Study, both performed in 1982 at McMaster University. Presented in a letter from Dr. Ann E. Robinson, Assistant Deputy Minister, Occupational Health and Safety Division, Ontario Ministry of Labour to the Royal Commission on Asbestos, 1 October 1982.

brake manufacturing.<sup>92</sup> It is not possible at present either to achieve such low fibre levels in general manufacturing or to measure them with conventional methods, nor has it been suggested to this Commission by any witness that such low levels could be achieved or measured in the foreseeable future. It is thus necessary to prohibit the use of crocidolite in Ontario lest workers be exposed to unacceptable risks. We therefore recommend that:

*7.12 The Government of Ontario should adopt regulations that would prohibit the use of crocidolite asbestos in Ontario workplaces without the approval of the Ministry of Labour. This approval should be granted only if the Ministry is satisfied that the health risks faced by workers exposed to this asbestos are far lower than the unacceptable risks estimated in this Report.*

Can we use the risk projection based on asbestos-cement pipe manufacture with crocidolite to estimate the risk presented by crocidolite exposure in other manufacturing situations or in non-manufacturing situations? Because we believe that the process generating the asbestos dust may affect the toxicity of the dust, it would be preferable to project risks in each process from epidemiological studies of that process. We do not have studies for other manufacturing processes involving crocidolite that are adequate for determining a dose-response function. In the absence of other information, we must assume that exposure to all crocidolite manufacturing processes presents the same health risks.

Even if no crocidolite is to be used in Ontario industry, some Ontario workers will continue to be exposed to crocidolite in some workplaces where crocidolite has already been installed, and must be disturbed, such as in buildings. Those workers who will be exposed to crocidolite in this way will in general be protected by the Proposed Regulation Respecting Asbestos on Construction Projects, which specifies control by procedure.<sup>93</sup> The use of respirators is often required, and the type of respirator depends upon the dust level in the workplace and the control limit that must be achieved for the worker. In the absence of a study that establishes a dose-response function for exposure to crocidolite in building insulation, we will rely again on the Finkelstein data. We believe that the respirators used should be sufficient to maintain the time-weighted average of a worker's breathing

<sup>92</sup> Compare Berry in Table 7.3, presenting a risk of 0.1 from an exposure of 0.2 f/cc to Finkelstein in Table 7.3, presenting a risk of 34 from an exposure of 0.2. The mortality rate per f/cc is over 300 times greater in the latter than in the former.

<sup>93</sup> Ontario, Ministry of Labour, Occupational Health and Safety Division, "Proposed Regulation Respecting Asbestos on Construction Projects and Related Codes," presented at a Public Meeting, 17 January 1983, Toronto. (Mimeographed.) This "Proposed Regulation . . ." is a revision of the "Notice of Proposed Regulation: Designated Substance — Asbestos on Construction Projects," *The Ontario Gazette*, vol. 115-33, Saturday, 14 August 1982, pp. 3194-3197. See Chapter 10 for recommendations regarding this proposed regulation.

exposure at or below 0.02 f/cc, 1/10 of the current control limit. We therefore recommend that:

**7.13 *The Code for Respiratory Equipment for Asbestos on Construction Projects should provide for the use of respiratory protection that will ensure that the worker's exposure does not exceed 0.02 fibres per cubic centimetre where crocidolite asbestos is in the air.***

This does not require that fibre levels of 0.02 f/cc be measured. Instead, the actual workplace fibre concentration which may exceed 1 f/cc must be measured, and a respirator chosen with a factor of protection that would expose the worker to no more than 0.02 f/cc.

**(b) Amosite**

In Chapter 5 we conclude that the health risk from exposure to a given measured fibre concentration of amosite was more severe than that from exposure to a similar concentration of chrysotile, but probably somewhat less severe than that presented by exposure to the same measured concentration of crocidolite. Unfortunately, we have little direct evidence of the health effects of amosite from quantitative epidemiological studies. The Enterline study of Johns-Manville factory workers included some workers exposed to amosite as well as to chrysotile, and some workers exposed to crocidolite. As we report in Chapter 5, Enterline found that exposure to amosite alone created greater health risks than exposure to a similar concentration of chrysotile alone, but he attached little significance to this result because he also found that exposure to a mixture of amosite and chrysotile was no more hazardous than exposure to chrysotile alone. His data do not, therefore, form a sound basis for projecting health risks arising from amosite exposure in manufacturing.

The major analysis of the health effects of amosite is found in the Selikoff studies of insulation workers who installed and removed asbestos-containing insulation in the United States and Canada. These workers were exposed to chrysotile and to a substantial amount of amosite in their work. While it is entirely possible that manufacturing processes using amosite might create risks different from insulation work involving amosite, in the absence of appropriate manufacturing data, we will use the insulation workers data for estimating risks both in insulation work and in manufacturing. According to the Selikoff data, summarized in Table 7.9, the short-term, normally exposed worker under the 1982 Ontario control limit of 0.5 f/cc would be exposed to risks of 4.1 deaths per 1,000 workers, while the long-term, highly exposed worker would face risks of 16 deaths per 1,000 workers. The risks just mentioned are somewhat above the fatality risk in construction work, and above that in manufacturing.

We believe that these risks are unacceptably high. However, if the

control limit were reduced to 0.1 f/cc, the estimated fatality risk would drop to 0.8 for the short-term, normal exposure, and 3.2 for the long-term, high exposure. We find that this health risk falls within the range of occupational health risks that have been found acceptable by society. No witness appearing before this Commission, however, has suggested that such low exposure levels could be achieved or measured reliably. We therefore recommend that:

*7.14 The Government of Ontario should adopt a regulation which prohibits the use of amosite in Ontario manufacturing unless and until it is demonstrated to the satisfaction of the Ministry of Labour that there is a measurement technology that will satisfactorily detect low amosite concentrations so that a 0.1 fibre control limit can be enforced with a reasonable degree of confidence.*

As is the case with crocidolite, some workers will continue to be exposed to amosite where it has already been installed in buildings and must be disturbed. We believe that the respirator requirements for workers on construction projects should protect against breathing more than 0.1 f/cc of amosite. We therefore recommend that:

*7.15 The Code for Respiratory Equipment for Asbestos on Construction Projects should provide for the use of respiratory protection that will ensure that the worker's exposure does not exceed 0.1 fibres per cubic centimetre where amosite asbestos is in the air.*

## **F.4 Insulation Work**

Removing existing insulation, or performing other maintenance or renovation activities on existing buildings, may expose some workers to amosite fibres because of the presence of amosite in existing insulation. The risks these workers face can best be estimated using the Selikoff data in Table 7.9. These workers will be protected by the Regulation Respecting Asbestos on Construction Projects, which we discuss in Chapter 10. Recommendation 7.15 will specify the appropriate respiratory protection for these workers. In Chapter 10 we discuss the work practices we believe necessary to maintain the exposure of insulation workers and other construction workers at or below an acceptable level.

## **F.5 Cost of Recommendations per Life Saved**

The risk assessment on which Table 7.9 is based can be combined with estimates of the cost of controlling workplace exposures to determine the incremental cost of life saving from adopting alternative control limits. It is interesting to compare these costs for three of our recommendations.

In the case of general chrysotile manufacturing, represented by friction products, the estimates of control costs by Dr. Gordon M. Bragg in his study for this Commission,<sup>94</sup> combined with the Table 7.9 risk assessments, suggest that moving from a 2 f/cc control limit to a 1 f/cc control limit involves a cost of about \$68 million for every work-related death avoided.<sup>95</sup> This is a high cost when compared to the cost data discussed in Section E above, and even when compared with the occupational health and safety costs in that section.

In contrast, the health risks from textiles are so high that the marginal cost per life saved of reduced fibre levels is far lower than in friction products. Using the cost data from a study by the Research Triangle Institute (RTI) and the Table 7.9 health effects predicted from the Dement data, we calculate that reducing the control limit from 2 to 1 f/cc would cost about \$0.66 million per life saved, and reducing it to 0.5 f/cc would cost \$1.6 million per life saved, still far below the cost of life saving in brake manufacture.<sup>96</sup> To be consistent with the cost of life saving in brake manufacture would require far more strict controls in textile manufacturing, and perhaps a ban. We do not have costs for achieving an acceptable risk level in textile manufacturing, but it seems likely that prohibiting this manufacture as we have done would be no more costly per life saved than the 1 fibre control limit for brake manufacturing.

The risk assessment for asbestos-cement production with crocidolite is again very high, so that the cost per life saved of exposure reduction is low. Using the RTI cost data<sup>97</sup> and the Finkelstein-based risk assessment, the cost of reducing the control limit from 2 to 1 f/cc would be about \$113,000 per life saved, while a reduction to a 0.5 f/cc control limit would cost about \$60,000 per life saved. A control limit of 0.2 f/cc would cost about \$1.1 million per life saved. Thus again, we appear justified by the cost figures in prohibiting the use of crocidolite in the manufacture of asbestos-cement.

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<sup>94</sup>Gordon M. Bragg, *The Technical Feasibility and Cost of Controlling Workplace Exposure to Asbestos Fibres*, Royal Commission on Asbestos Study Series, no. 7 (Toronto: Royal Commission on Asbestos, 1982), Tables 4.2 and 4.5, reproduced as Tables 6.9 and 6.10 in Chapter 6 of this Report.

<sup>95</sup>Meeting a 1 f/cc control limit costs \$1,350 per operator per fibre per year more than meeting a 2 f/cc control limit, or \$13.5 million for 1,000 workers for 10 years. Table 7.9 shows that reducing the control limit by 1 f/cc saves 0.2 lives for short-term, normal exposure. The cost per life saved is thus \$13.5 million divided by 0.2, or about \$68 million.

<sup>96</sup>Research Triangle Institute, "Asbestos Dust Technological Feasibility Assessment and Economic Impact Analysis of the Proposed Federal Occupational Standard," draft report prepared for the U.S. Department of Labor, Occupational Safety and Health Administration, Research Triangle Park, North Carolina, September 1978. (Mimeographed.) The cost is \$10.5 million for 1,000 employees, saving 16 lives, or about \$0.66 million per life saved.

<sup>97</sup>Ibid. The cost is \$8.7 million for 1,000 employees, saving 77 lives, or \$113,000 per life, at a 1 f/cc control limit. Achieving 0.5 f/cc adds \$2.4 million in cost, and 0.2 f/cc adds \$28 million.

products on the grounds that this is no more expensive as a way of saving workers' lives than the recommended controls on brake manufacture.

## F.6 General

We have proposed regulations that distinguish among types of asbestos and that are particularly restrictive for specific manufacturing operations. We believe that the special hazards presented by textile operations result from the size distribution of fibres and perhaps their surface chemistry in the atmospheres of such plants. Even when the current membrane filter method of measuring airborne fibre levels reveals that a particular fibre level is achieved, the proportion of medically relevant long, thin fibres is greater in these plants than in other plants. If we knew for certain the toxicity of different fibre sizes and types, and the effects of surface chemistry, and if it were possible to measure these types and sizes and chemistry separately, then varied control limits could be specified that would provide equal protection in any plant using any type of asbestos. Our knowledge, however, is incomplete. The theories about the toxicity of fibre types, sizes, and surface chemistry are not precise. We have, therefore, relied on studies that have proved that certain situations have caused serious health problems in the past, and we have prohibited the recurrence of those situations directly. If at some time in the future the relationship between fibre type, size, and surface chemistry — and the resulting health effects — is sufficiently well developed that it is possible to achieve acceptable risk levels by specifying control limits alone, then the prohibitions on certain manufacturing operations should be replaced by the proper control limit.

Our recommendations above have been based on the hypothesis that asbestos fibres differ in their toxicity depending upon the size and perhaps the surface chemistry of the fibre. Because different types and manufacturing processes yield fibres that differ in their toxicity, then some of these types and processes should be subject to special restrictions. We recognize that these views are not held universally. However, the Dement and Finkelstein studies, which have emerged only in the last few years, compel the conclusion that health risks in different workplaces have differed greatly. The differences in estimated risk between the Dement and Finkelstein studies, on the one hand, and the J.C. McDonald and Berry studies, on the other, are so great that we feel confident in treating the risks of different fibre types and processes as truly different and regulating them accordingly. To apply a single control limit to all fibre types and processes would require that we ignore the Dement and Finkelstein studies, despite their being accepted in the scientific literature and to ignore almost all studies of the health effects of crocidolite. We find no reason to reject this evidence, and we are, therefore, logically led to recognize these observed differences in health risks in our recommendations for worker protection. With particular

respect to differentiating among industrial processes for regulatory purposes, ours is, to the best of our knowledge, the first official study to frame formal recommendations to the effect that asbestos, in this instance chrysotile, requires different regulatory responses in different industrial processes.

How can employers be encouraged to reduce fibre levels below the numerical control limits that have been recommended? Under the *Occupational Health and Safety Act* there is a legal duty to reduce fibre exposure where practical, and this will presumably be encouraged by inspectors who can order a firm to reduce fibre levels even when they are in compliance with the 1 fibre control limit if in the Ministry's judgement this reduction is practical. In addition, the joint health and safety committee in any plant could work towards reducing fibre levels, even when the numerical control limit is met. Because we believe that compliance with this control limit will reduce asbestos risks to a level well below that of other risks faced by Ontario workers, we think it is appropriate that the joint committees share responsibility for deciding whether they wish to pursue health and safety by reducing fibre levels or by other means within a particular plant. The matter of enforcement is pursued in Chapter 8.

## G. Other Fixed Workplace Exposure: Automotive Brake Mechanics

Approximately 40,000 automotive mechanics in the province of Ontario may be exposed in varying degrees to asbestos as a result of their work on brake maintenance and repair in 11,000 garages in the province. In Chapter 6 we note that this exposure may arise from two quite distinct sources: blowing dust from old drum brakes, and grinding or bevelling new brake shoes. The time-weighted average asbestos exposure caused by blowing dust from old drum brakes would, we conclude, generally be below 1 f/cc, in part because a considerable portion of this dust consists of material other than asbestos, and in part because most workers would spend only a few minutes per day actually blowing dust from brake drums. In contrast, grinding and bevelling of brake shoes can generate much higher dust levels, most of which consists of chrysotile asbestos. There are few shops in Ontario, however, where grinding and bevelling of new brake drums take place with any frequency.

In principle, all workers in automotive maintenance shops who may be exposed to asbestos dust as a result of brake repair are covered by the Regulation Respecting Asbestos since the shops would be places where "... asbestos is present . . . handled . . . and at which the worker is likely to inhale or ingest asbestos."<sup>98</sup> Thus, the 1 f/cc control limit for chrysotile

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<sup>98</sup>Regulation Respecting Asbestos, s. 3(1).

contained in section 4(1) must be complied with. However, we consider it impractical to expect the 11,000 automotive shops across the province to conduct regular monitoring of the asbestos exposures of their mechanics. Nor would it be economical for the Ministry of Labour to perform such extensive monitoring, which would have to cover more than 15 times as many workers as are exposed to asbestos in manufacturing plants in the province. Fortunately, such monitoring is as unnecessary as it is impractical. Simple control procedures are identified in Chapter 6 that would bring the workers' asbestos exposure well below the 1 f/cc control limit. The situation of brake mechanics seems similar to that of construction workers, for whom regular air monitoring is not used, but instead protection is enforced by "regulation by procedure." In place of air monitoring, the Proposed Regulation Respecting Asbestos on Construction Projects (and our proposals for protecting workers from asbestos on construction projects in Chapter 10) specify procedures which must be followed to ensure worker safety without requiring the monitoring of air quality.<sup>99</sup> We believe that the same approach should be followed for brake mechanics.

While the exposure of brake mechanics to wear debris from blowing dust from old drum brakes will generally cause asbestos fibre levels below the 1 f/cc control limit, some control action may be desirable. Even if the wear debris is predominantly not asbestos, it still contains durable material of respirable size. Prudence would suggest taking some steps to control inhalation of this material. Furthermore, the Regulation Respecting Asbestos requires not only that the control limits be met, but that exposures be reduced to the lowest practical level. We conclude in Chapter 6 that the use of wet removal methods, in which the dust is gathered on a damp sponge, cloth, or brush, and essentially washed away, is both effective and economical. We believe that the use of wet removal methods is justified for old drum brakes. We therefore recommend that:

*7.16 The Ministry of Labour, in applying the control limits of the Regulation Respecting Asbestos to automotive brake repair operations, should accept the use of wet methods of brake drum cleaning as prima facie evidence that the Regulation has been complied with.*

The high fibre concentrations observed during grinding and bevelling of brake shoes, in contrast to blowing wear debris from old brakes, and the low likelihood that this grinding has converted asbestos fibres into non-asbestos fibres, lead us to seek a more stringent protection regime for workers who perform these operations than is necessary for cleaning of brake drums. Workers engaged in grinding and bevelling of brake shoes may be protected by wearing a respirator or by attaching an exhaust venti-

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<sup>99</sup>Ontario, Ministry of Labour, Occupational Health and Safety Division, "Proposed Regulation Respecting Asbestos on Construction Projects and Related Codes."

lation system to the grinding machine. The appropriate procedure depends upon the situation in which the work is performed. In shops where grinding and bevelling are rarely necessary, it should be sufficient for the worker to use a respirator while grinding brake linings and to clean the grinding machine area regularly using wet methods. In shops where grinding and bevelling take place frequently, the extra cost of attaching a ventilation system to the grinding machine would be warranted by the considerable extra protection that this affords to the operator himself and to other nearby workers. We therefore recommend that:

*7.17 The Ministry of Labour, in applying the control limits of the Regulation Respecting Asbestos to exposures of workers engaged in grinding and bevelling of brake drums in automotive brake repair operations, should accept as evidence that the Regulation is complied with:*

- (i) that the operator is wearing a respirator while grinding and while cleaning the debris afterwards with wet methods, in shops where this operation occurs rarely; and*
- (ii) that the machines are equipped with local exhaust ventilation, in shops where grinding of brake shoes occurs frequently.*

The above recommendations should solve the problem of the impracticability of regular air monitoring to determine compliance with the control limits specified in section 4 of the Regulation Respecting Asbestos. The remainder of the Regulation Respecting Asbestos, however, appears to apply to automotive repair shops and imposes a considerable burden on the large number of operations, each of which presents, as we have indicated above, modest worker exposures to asbestos. The Regulation can be interpreted to mean that every automotive repair shop must prepare an assessment of the likelihood of worker exposure to asbestos,<sup>100</sup> prepare an asbestos control programme,<sup>101</sup> and implement air monitoring and medical surveillance of workers.<sup>102</sup> We consider it eminently unrealistic to expect that this is being done, or will be done, in all 11,000 automotive shops across the province. Furthermore, we believe that it is not sensible to implement this elaborate machinery for what we have determined to be minor and isolated asbestos exposures.

We conclude in Chapter 6 that modest precautions will yield worker exposures well below the 1 f/cc limit, except that where grinding of brake shoes is performed frequently, exhaust ventilation is required. No purpose would be served by establishing the elaborate regulatory machinery in all these shops that is appropriate for manufacturing operations where substantial exposure may be experienced. All that is necessary is to encourage

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<sup>100</sup>Regulation Respecting Asbestos, ss. 6(1), 8, 9, 10.

<sup>101</sup>Ibid., s. 7(1).

<sup>102</sup>Ibid, ss. 7(2), 11, 12, 13, 14, 15, 16.

that minimal precautions be taken in these operations. We therefore recommend that:

*7.18 The Regulation Respecting Asbestos should be amended to specify that sections 6 through 16 do not apply to workplaces where the only exposure to asbestos arises out of the repair and maintenance of automotive brakes, unless grinding of brake shoes is performed frequently.*

Research conducted by Commission staff in June 1981 revealed unfortunately that only a small fraction of the brake repair shops visited in Metropolitan Toronto treated brake dust generated from bevelling and grinding consistently with the procedures discussed above. In fact, in a number of locations we found that if any effort was expended in control, it was directed to controlling wear debris exposure via wet removal, while grinding and bevelling were undertaken with little or no protection. Training programmes for auto mechanics fail generally to convey the appropriate information about risks and worker protection. Considering the relative ease with which exposure to brake dust may be controlled, the problem of negligent removal seems to indicate not only a lack of available control equipment but an inadequate provision of information in the workplace as well. Since few of the workers involved in brake repair are organized, the task of informing workers of proper work practices falls onto both employers and the Minister of Labour.

The large number of brake repair shops, and the even larger number of mechanics who work on brakes, render difficult the problem of communicating the gist of the above recommendations to these workers. Fortunately, the risk faced by these workers is quite low, with the exception of those workers who regularly grind or bevel new asbestos-containing brake shoes. We therefore recommend that:

*7.19 The Ministry of Labour should develop a modest information programme to communicate with the vast number of auto mechanics in Ontario the appropriate work practices as described in Recommendations 7.16, 7.17, and 7.18. A more intensive programme of communication should be designed to reach those mechanics working in brake specialty shops where, in particular, a considerable volume of grinding of new brake shoes is performed. The Ministry should also communicate appropriate practices to the secondary and post-secondary institutions in Ontario where auto mechanics training is currently provided.*

# **Appendix to Chapter 7**

## **Predicting Workplace Health Risks**

**Ronald J. Daniels\***  
**and**  
**Robin S. Roberts\*\***

### **Section 1:**

#### **Dose-Response Models for Asbestos-Related Disease**

#### **A. Introduction**

This Appendix outlines the rationale and mechanics of the model employed to predict the risks of asbestos-related disease presented in Chapter 7. Included in the Appendix is a complete set of results of the health effects simulations generated by making alternative assumptions concerning the characteristics of the workforce and the context in which their exposure is received. Specifically, we evaluate the impact of: (i) the duration and intensity of fibre exposure; (ii) population smoking habit; (iii) the age at which the population is first exposed to asbestos; and (iv) the frequency of population turnover, on the level of expected health risk.

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The authors would like to thank Mr. Julian Peto, now at the Institute of Cancer Research, Surrey, England, for extensive and helpful comments on an earlier draft of this Appendix. Authors of several studies discussed here, especially Dr. Murray M. Finkelstein, were helpful in responding to requests for clarification about their studies.

The Appendix is divided into three sections. Section 1 focuses on the development of dose-response functions specific to asbestos-related disease. These functions are then incorporated into a model which accounts not only for the gender, age, and smoking characteristics of the exposed population, but for their survival prospects as well. In Section 2 we review the various epidemiological studies conducted on populations occupationally exposed to asbestos and extract data from these studies that will enable us to extrapolate the health experience of historically exposed populations to future populations. Finally, in Section 3 we present the results of the simulations discussed above. Some of the health effects data that were used here are presented in the Appendix. Often, however, conclusions reached in Chapters 2 through 5 regarding the medical evidence will be referred to here, without full reference to the original sources. For a careful review of the medical evidence on health effects, see Chapters 2 through 5 of this Report.

## **B. Dose-Response Modelling and Asbestos-Related Disease**

The first stage in calculating the future incidence of an occupational disease involves the construction of a dose-response function. The dose-response function relates the magnitude of a certain dose of a hazardous substance to the health effects that ensue. The measurement of dose is a complex matter and is discussed in Chapters 4 and 5 of this Report. Except when otherwise specified, we will represent the cumulative dose of asbestos as the product of intensity times duration. Since the behaviour of the dose-response function is based on data supplied by animal and epidemiological studies, deficiencies in these studies will also affect the quality of the resultant dose-response metric. For instance, epidemiological studies may be weakened by inaccurate measurements of dose and/or health response, while the results of animal studies may not extrapolate to man because of the physiological differences between humans and the species investigated.

Even if an epidemiological study is selected in which accurate measurements of dose and health response are found, the exposure of the study population may not span the full range of exposures that are now of interest. In fact, most worker populations that have been studied experienced past exposures to hazardous substances which were relatively large compared to current exposures. It is difficult to estimate a model from such data that is reliable for low doses.

To utilize the data furnished by a population previously exposed to a hazardous substance, a dose-response curve is fit to data which are characterized by many high-dose observations and few observations in a low-dose region. This step is accomplished tentatively at best, as there are a number

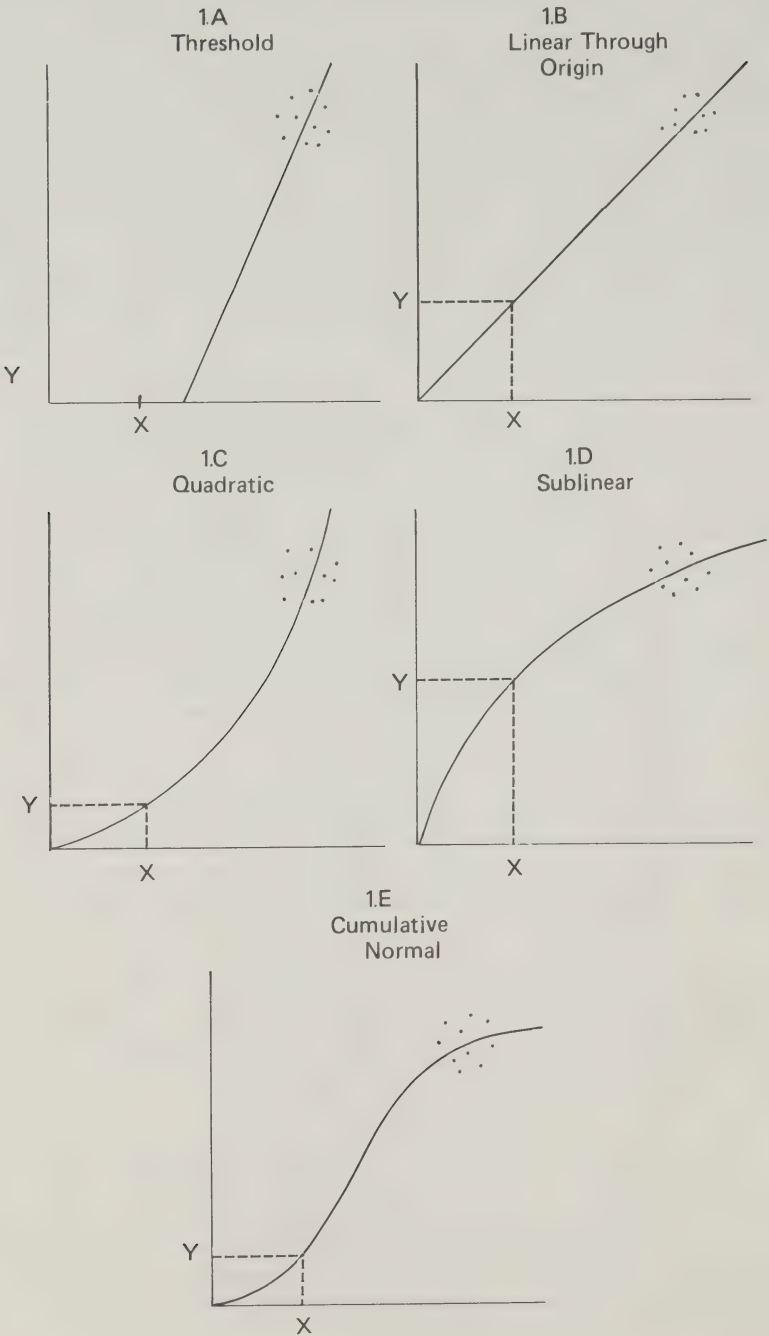
of different dose-response models which could fit the mass of high-dose data with equal precision. Unfortunately, these competing dose-response functions yield very different results at low doses, which are of paramount importance for contemporary occupational health risk assessment.

The dissimilarity in the behaviour of alternative dose-response functions at low doses means that the selection of one function over another will produce very different predictions of disease at these levels, as shown in Figure 1. Each of the dose-response functions depicted measures the cumulative dose of a hazard on the horizontal axis and response in terms of excess risk of mortality or incidence of disease on the vertical axis. Figure 1.A shows a threshold-response function. Below some limit value of dose there is no associated excess sickness or mortality. Figure 1.B illustrates a more frequently observed dose-response function that is linear through the origin. In this model a given increase in dose is matched by proportional increases in disease risk. Figures 1.C and 1.D depict dose-response models in which the response is a power function of the dose. In Figure 1.C (quadratic function) the response increases in proportion to the square of the dose, and in Figure 1.D (sublinear function) the response increases in proportion to a power of dose which is less than unity. Finally, Figure 1.E (cumulative normal) demonstrates the dose-response function in which response increases as if the distribution of susceptibility to a hazard was normally distributed. For a given low dose "X," notice that the magnitude of the predicted response "Y" varies significantly depending on which dose-response model is chosen: the risk predicted from dose "X" is greatest with the sublinear model, while the threshold model predicts that no health risk will result from this exposure.

What basis do we have for choosing the function best suited for modelling the future incidence of asbestos-related diseases? In the cases of lung cancer and mesothelioma, the available data are consistent with the assumption that excess mortality is proportional to the intensity of the exposure, although as Figure 1 shows, such consistency does not rule out other relationships. Most recent studies that have considered these data have chosen from the competing models a linear dose-response model as a reasonable compromise. The linear model is scientifically plausible, easy to work with, and conservative in that most other models would lead to lower, not higher, predictions of disease. We will use the linear model in the analysis that follows, for lung cancer and mesothelioma.

The decision not to enlarge our study to include predictions of other asbestos-related diseases was militated by a number of factors. Insofar as asbestosis is concerned, we have assumed that the amount of disease which would accrue from current exposures to asbestos would be negligible. This assumption is based upon the conclusion in Chapter 5 that clinical asbestosis is unlikely to occur at exposure levels that will prevail in the future. As well, we have not included predictions of other asbestos-related diseases

Figure 1  
Alternative Dose-Response Curves Fitted to a  
Set of Observed Data Points



such as gastrointestinal and laryngeal cancer. Although a number of epidemiological studies have found elevated levels of mortality from these cancers among asbestos workers, the risk of experiencing these diseases has not been consistently demonstrated across all cohorts. Further, in the cohorts where excess rates of gastrointestinal and laryngeal cancer have been detected, the absolute amount of mortality from these diseases is much lower than the mortality from lung cancer, mesothelioma, and asbestosis. These factors, when combined with the uncertainty surrounding dose-response modelling for these diseases, have led us to exclude consideration of the effect of asbestos exposure on the levels of gastrointestinal and laryngeal cancer in our simulations.

## **C. Lung Cancer Dose-Response Function**

### **C.1 The Measure of Lung Cancer Disease**

Workers exposed to asbestos suffer an increased risk of lung cancer, but the disease also occurs in those not exposed to asbestos. To delineate between the amount of disease induced by exposure to asbestos and the amount of disease that would otherwise occur, the response metric of excess relative risk is employed.

The excess relative risk measure is obtained by comparing the health experience of a cohort exposed to a deleterious substance to the health experience of an unexposed cohort with similar population characteristics. The comparison yields a ratio of relative risk. By subtracting 1 from the relative risk value (to account for the background level of lung cancer), an excess relative risk measure is generated. The excess relative risk values derived from epidemiological studies will serve as the measure of the effect of asbestos on lung cancer incidence. The magnitude of this excess relative risk will vary from study to study because of: (i) different intensities and durations of exposure; (ii) varying fibre types and sizes; (iii) the personal characteristics of the population under study; and (iv) the differences in each study's design.

The health end point for which the excess relative risk measure will be derived is mortality from lung cancer. Since the time between diagnosis of lung cancer and death will rarely exceed 5 years, incidence of lung cancer and mortality from that disease may be treated as being virtually synonymous.

### **C.2 Selection of a Linear Dose-Response Function**

The dose-response model we employ in calculating the future incidence of lung cancer is linear through the origin with respect to cumulative

exposure to asbestos. Application of a linear function for estimating lung cancer risks from asbestos has been widely endorsed by members of the scientific community. For instance, Dr. William J. Nicholson, after discussing a variety of dose-response relationships and examining data gathered from epidemiological studies, concluded that the linear dose-response function is best suited for modelling asbestos-related lung cancer.<sup>1</sup> Dr. Nicholson found the alternative dose-response functions (log-probit, logit, multi-stage, one-hit, and threshold functions), developed for extrapolating results of animal data to human populations, deficient because the experimental data do not favour one model over another. Instead, Dr. Nicholson prefers the analysis developed by Dr. Kenny S. Crump et al. which finds that “. . . the added risk of cancer above ‘background’ from an external exposure is likely to be proportional to dose.”<sup>2</sup> Further, Dr. Nicholson has stated that “. . . in the range of interest for occupational asbestos exposures, predictions from a linear extrapolation are indistinguishable from those of either the log-probit, logit, or any multi-stage model. . . .”<sup>3</sup>

Dr. Nicholson’s conclusions, based on a survey of the theoretical literature, are buttressed by the findings reported in several epidemiological studies. These studies are discussed in depth in Chapter 5.

The adoption of a linear dose-response function with respect to cumulative exposure means that there is no greater weight attached to the effect of early as opposed to later exposure to asbestos. In this model, the health effects of a cumulative exposure of 30 fibres per cubic centimetre-years (f/cc-yrs) are the same regardless of whether the dose was received for 10 years at 3 fibres per cubic centimetre (f/cc) or 2 years at 15 f/cc. Also, since this model is linear through the origin, no exposure to asbestos can be considered “safe.” Even relatively small exposures to asbestos will entail some additional risk of lung cancer.

### **C.3 Excess Relative Risk of Lung Cancer Independent of Age**

The model used here assumes that the level of excess relative risk is solely a function of cumulative exposure and entirely independent of age at first exposure and pre-existing risk. This point is supported by the data presented in Figure 2 below. In this figure, the cohort studied by Selikoff,

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<sup>1</sup>William J. Nicholson, *Dose-Response Relationships for Asbestos and Inorganic Fibers* (New York: Environmental Sciences Laboratory, Mount Sinai School of Medicine of the City University of New York, 15 February 1981), pp. 9–13.

<sup>2</sup>*Ibid.*, p. 11. See also, Kenny S. Crump et al., “Fundamental Carcinogenic Processes and Their Implications for Low Dose Risk Assessment,” *Cancer Research* 36 (September 1976): 2973–2979.

<sup>3</sup>Nicholson, *Dose-Response Relationships for Asbestos and Inorganic Fibers*, p. 11.

Hammond, and Seidman [hereafter Selikoff] of insulation workers in the United States and Canada, first exposed to asbestos at ages 15 to 24, experienced a pattern of increasing relative risk that mirrors the pattern evident for workers drawn from the same cohort but first exposed to asbestos at ages 25 to 34.<sup>4</sup> While the slopes of the two functions are similar, the only difference between the two is their separation by a period of 10 years. This difference corresponds to the approximate difference between the mean age of first exposure of the two groups. While both curves in Figure 2 show a trail-off in disease incidence after 30 or so years, this feature is not incorporated in our model, for reasons discussed below.

#### **C.4 Lag Between Onset of Exposure and Increase in Excess Relative Risk About 10 Years**

Figure 2 also indicates that the time period between first exposure and manifestation of excess relative risk is fairly short. In the Selikoff cohort, a delay of about 10 years is experienced before an increase in relative risk is detected. A comparable graph from the study by Seidman, Selikoff, and Hammond, which also plots relative risk as a function of time since first exposure, reveals that the relative risk of developing lung cancer becomes elevated about 10 years after exposure commences.<sup>5</sup> See Figure 3. In order to capture this effect in our model, we will allow a delay of 10 years between the onset of exposure and the resulting increase in relative risk. Thus, the excess relative risk resulting from the first 10 years of exposure will be fully experienced at the end of the delay period. Thereafter, any increase in cumulative exposure will exert a direct impact on the response function.

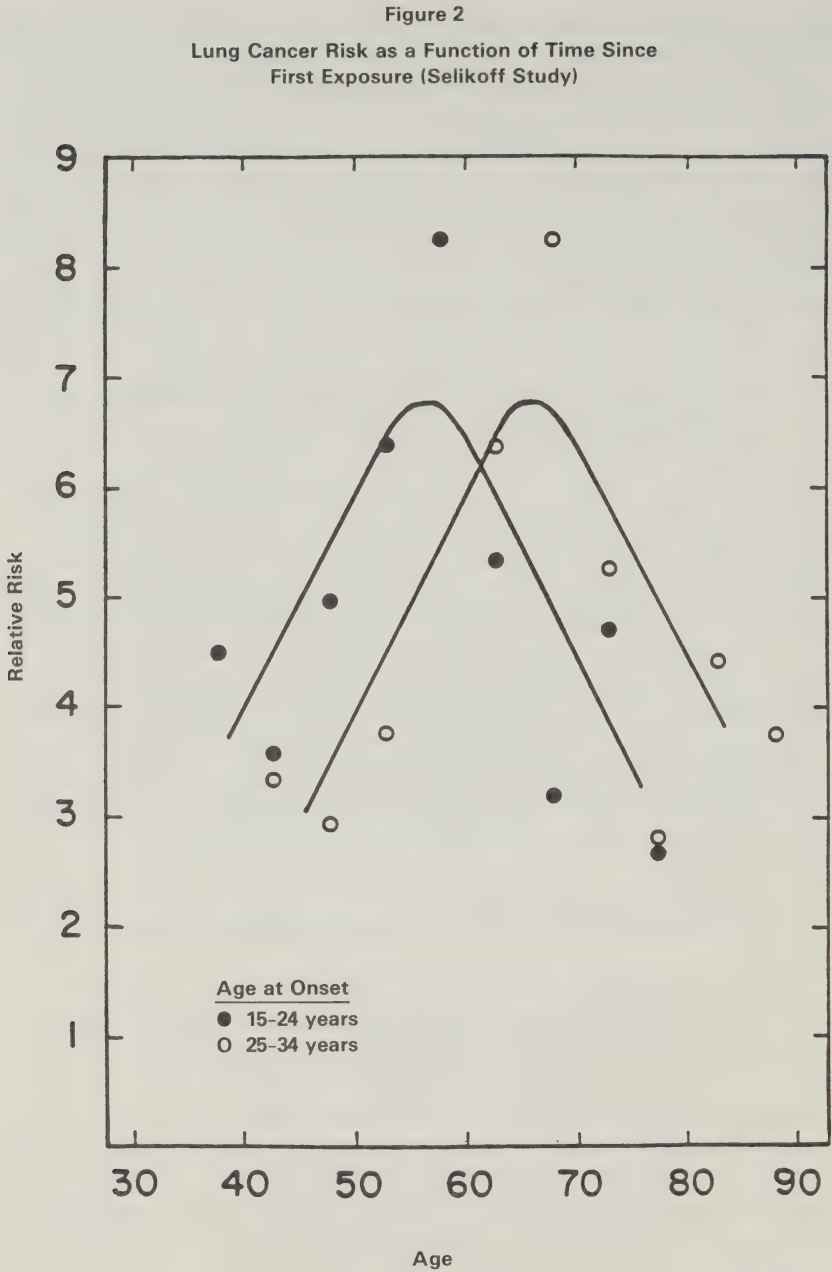
#### **C.5 Excess Relative Risk as a Function of Time**

Another important feature of the model concerns the behaviour of the excess relative risk function with respect to time. The model assumes that after the 10-year period any increase in cumulative exposure will cause a similar increase in excess relative risk and will remain constant after total cumulative exposure is experienced. The reasonableness of presuming that excess relative risk of a given cumulative exposure to asbestos remains constant after cessation of exposure is somewhat problematic. Dr. Selikoff's epidemiological study of insulation workers found that the excess relative risk of lung cancer increased as cumulative exposure increased and then

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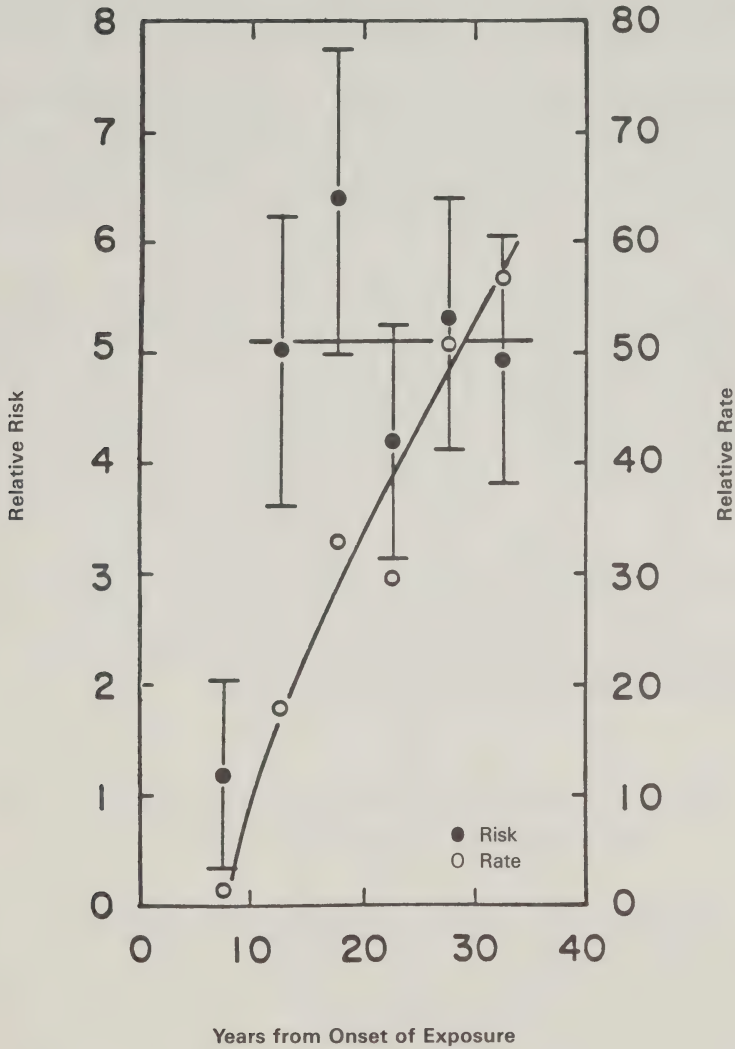
<sup>4</sup>See Irving J. Selikoff, E. Cuyler Hammond, and Herbert Seidman, "Mortality Experience of Insulation Workers in the United States and Canada, 1943-1976," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 91-116.

<sup>5</sup>See Herbert Seidman, Irving J. Selikoff, and E. Cuyler Hammond, "Short-Term Asbestos Work Exposure and Long-Term Observation," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 61-89.



SOURCE: William J. Nicholson et al., "Cancer from Occupational Asbestos Exposure: Projections 1980-2000," in *Banbury Report 9: Quantification of Occupational Cancer*, eds. Richard Peto and Marvin Schneiderman ([Cold Spring Harbor, New York]: Cold Spring Harbor Laboratory, 1981), Figure 1, p. 89.

Figure 3  
Lung Cancer Risk as a Function of Time  
(Seidman Study)



SOURCE: William J. Nicholson et al., "Cancer from Occupational Asbestos Exposure: Projections 1980-2000," in *Banbury Report 9: Quantification of Occupational Cancer*, eds. Richard Peto and Marvin Schneiderman ([Cold Spring Harbor, New York]: Cold Spring Harbor Laboratory, 1981), Figure 3, p. 92.

after remaining constant began to trail off after 30 years following onset of exposure. (See Figure 2.) It is likely that this trail-off in lung cancer relative risk may be related to the high past exposures experienced by the cohort; that is, workers who have had heavy asbestos exposure would suffer the risk of early removal from a competing asbestos-related disease such as asbestosis or mesothelioma. If some workers, whether for genetic or environmental reasons, are more susceptible to an asbestos-related disease than others it is conceivable that they would develop lung cancer early and be removed at that stage from the cohort. As a result, they would not survive to a point where the likelihood of developing an asbestos-related lung cancer was significant. Thus, removal via a competing cause of death would account for the trail-off in lung cancer relative risk as time since first exposure increases.

Although the trail-off effect was detected in the Selikoff cohort, most of the other epidemiological studies do not contain sufficient follow-up data either to reinforce or to refute the existence of this effect. In fact, in another epidemiological study with lengthy follow-up, Dr. Seidman and his colleagues were unable to find unequivocal evidence of a trail-off of excess relative risk with respect to time. Thus, motivated by the dearth of comprehensive epidemiological data which would allow us to define precisely the trail-off effect, we have refrained from building this effect into our model. Another reason to exclude a trail-off effect relates to our skepticism of the likelihood of substantial population removal by competing causes of death at low exposure levels. Recall that we have assumed that the level of asbestosis mortality (historically a major source of competition) accruing from current and future exposure levels will be negligible.

### **C.6 Lung Cancer Dose-Response Function Dependent on Background Lung Cancer Rate**

To express response in terms of the excess lung cancer rate rather than excess relative risk, it is necessary to multiply the background lung cancer rate by the excess relative risk. This causes the response metric, previously a function solely of cumulative exposure, to be sensitive to the characteristics of the underlying population. That is because factors such as smoking, gender, and age which influence the level of lung cancer mortality in a population will exert a similar impact on the response metric when the product of excess relative risk and the underlying lung cancer rate is used.

However, reliance on a model in which excess relative risk is applied to the background lung cancer rate has important implications for the combined effect of smoking and asbestos exposure on lung cancer risk. Hammond, Selikoff, and Seidman found that smoking exerts a multiplica-

tive effect on the lung cancer dose-response relationship.<sup>6</sup> This has been confirmed by a number of researchers and by this Commission, in Chapter 5. This means that if the excess relative risk caused by a given cumulative exposure is 5, the risk to asbestos workers who smoke becomes the background lung cancer rate for non-smokers multiplied by the relative risk of lung cancer entailed by smoking multiplied by 5. This point may be more easily understood by reference to Figure 4.

Our model predicts that in the absence of asbestos exposure and smoking, workers in the general population will experience a risk of lung cancer mortality that rises with age as curve A in Figure 4. For workers aged 20 years, the rate of lung cancer mortality is about 1,400 times lower than that experienced by workers aged 80 years. For unexposed workers who smoke, the lung cancer mortality curve shifts upwards by a constant factor. (See curve C.) Exposure to asbestos causes these curves to shift upwards by a factor determined by the product of cumulative exposure and the value of excess relative risk derived from the dose-response function. While this factor is the same for both smoking and non-smoking exposed workers, because the factor is applied to the smoking-specific background lung cancer rates, the magnitude of the final lung cancer rate for workers with equivalent cumulative exposures will differ in accordance with their smoking habit. (See curves B and D.)

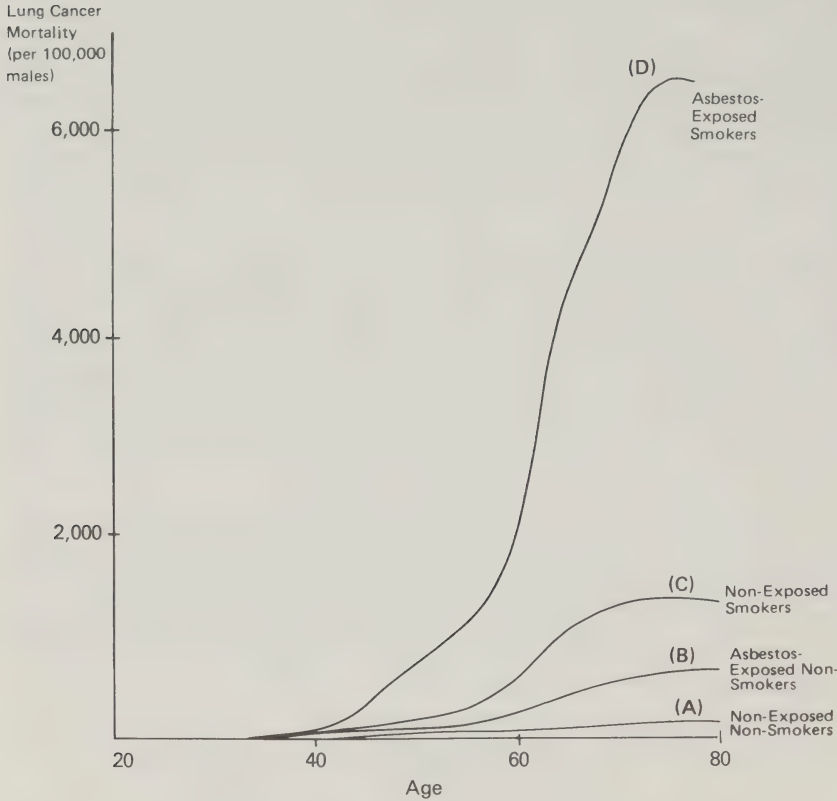
The exposed population whose experience is simulated in this graph was first exposed to asbestos at age 20. Notice that even if we removed the delay constraint, the effect of exposure on lung cancer mortality at the earliest stages of their exposure is negligible. This is because in the years immediately following first exposure, the background level of lung cancer in the general population is quite low. Since the mortality rate is not significant at this stage, altering this rate multiplicatively by the appropriate excess relative risk value will not significantly affect lung cancer mortality.

When the actual mortality experience for a given cohort is plotted and stratified by age at first exposure, the same pattern that we have proposed for the model is evident. See Figure 5. Here, lung cancer mortality for smokers derived from Dr. Selikoff's insulation cohort is compared to an unexposed population. For workers first exposed at ages 15 to 24, the mortality curve is coincident with the mortality curve for the unexposed population until the late 30s. Thereafter, the mortality rates for exposed workers rise above the rate for unexposed workers by an amount dependent upon the intensity and duration of the exposure.

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<sup>6</sup>E. Cuyler Hammond, Irving J. Selikoff, and Herbert Seidman, "Asbestos Exposure, Cigarette Smoking and Death Rates," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 473-490.

Figure 4  
Predicted Lung Cancer Mortality as a Function of Age,  
Smoking, and Asbestos Exposure



**Figure 5**  
**Lung Cancer Mortality Among North American Insulation Workers**  
**(Cigarette Smokers Only)**



SOURCE: Adapted from: Julian Peto, "Dose and Time Relationships for Lung Cancer and Mesothelioma in Relation to Smoking and Asbestos Exposure," in *Zur Beurteilung der Krebsgefahren durch Asbest* [Proceedings of the Bundesgesundheitsamt Asbestos Symposium], Berlin: February 1982, bga Schriften, MMV Medizin Verlag München, in press, 1983, Figure 6.

## C.7 Combining Disease Rates with Survival Probabilities

The last theoretical issue to be resolved for our model concerns the age distribution of lung cancer mortality. Hitherto, we have dealt with lung cancer mortality in terms of disease rates. The mortality curves we have developed show that the rate of lung cancer mortality is highest when the population is oldest. However, these mortality rates must be viewed against the backdrop of the likelihood of an individual surviving to an age when these mortality rates are greatest. Since lung cancer is not the only source of death which an exposed population would experience, we must take into account the removal of members of the simulated population by death from other causes. So doing will cause the actual distribution of lung cancer deaths in an exposed cohort to fall below the levels we would expect without any natural removal.

Figure 6 clarifies this point, showing the yearly probability of death at different ages for a 20 year old male. If risk of lung cancer mortality is seen to increase as in Figure 6.A, this must be considered in the context of the survival curve drawn in Figure 6.B. A high risk of death from lung cancer at age 80 in Figure 6.A must be multiplied by the probability of surviving to age 80. Since it is likely from Figure 6.B that the worker will have died by some other cause before reaching that age, the actual probability of lung cancer mortality at age 80, which is shown in Figure 6.C, deviates from the level indicated in Figure 6.A.

However, as a result of asbestos exposure, the evaluation of the risk gradient at the higher end of the dose-response function will still be responsible for a great many lung cancer deaths in that range, and as a result the majority of lung cancer deaths related to asbestos will occur in older workers.

## C.8 The Full Lung Cancer Model

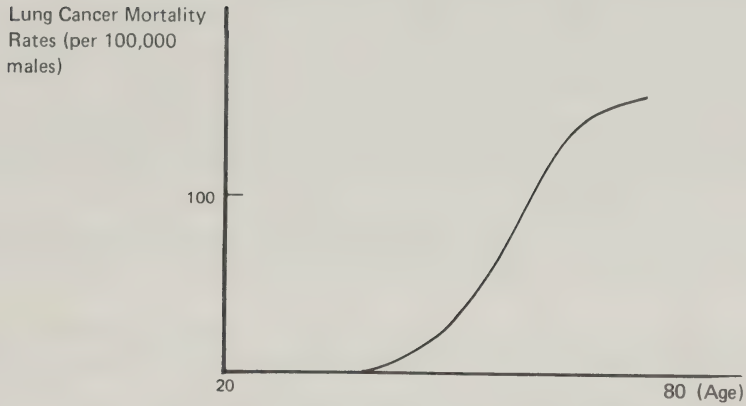
From our preceding discussion, it is clear that any attempt to model a lung cancer dose-response function related to asbestos must be sensitive to the lung cancer mortality rate which would occur in the absence of exposure to asbestos. Ideally, such rates should be age-, gender-, and smoking-specific. In addition, it is important to account for worker survival patterns. The model we employ incorporates all of these variables. The number of excess deaths per year at age  $a$  in a cohort of size  $NOW$  first exposed to asbestos at age  $A$  is given by the following equation:

$$IE(a) = C * FCC * D * NOW * LU(a) * S(a) / S(A),$$

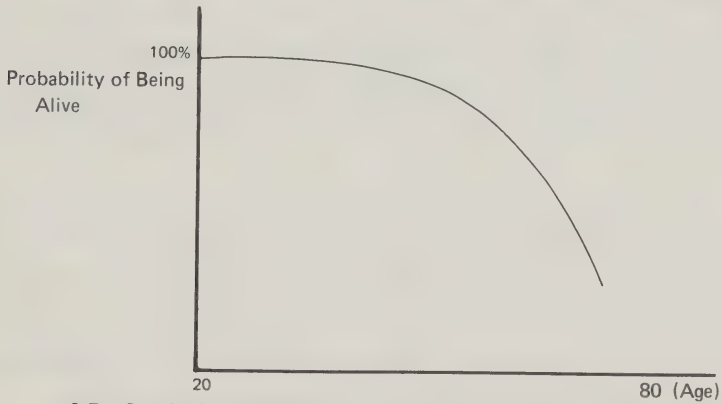
Where:

$IE(a)$  = number of excess lung cancer deaths per year at age  $a$  resulting from asbestos exposure beginning at age  $A$ ;

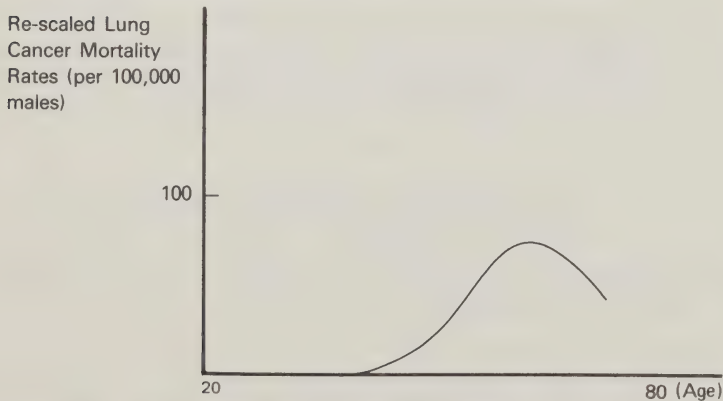
**Figure 6**  
**Yearly Probability of Lung Cancer Mortality**



**6.A Lung Cancer Risk Gradient for Non-Smoking Males**



**6.B Survival Probabilities for Non-Smoking Males**



**6.C Lung Cancer Risk Gradient Re-scaled for Survival**

$C$  = a proportionality constant derived from epidemiological studies which relates the cumulative dose of asbestos exposure to the excess relative risk of lung cancer;

FCC = average intensity of exposure to asbestos in f/cc;

$D$  = duration of exposure to asbestos;

NOW = number of workers exposed;

$LU(a)$  = the age-, gender-, and smoking-specific death rate for lung cancer;

$S(a)$ ,  $S(A)$  = the cumulative probability of survival to ages  $(a)$  and  $(A)$  respectively.

The lifelong excess mortality of the cohort is the sum of  $IE(a)$  from  $a$  equals  $A$  to 80.

The input data are derived as follows:  $C$  values are derived from various epidemiological studies which investigated disease incidence among workers in various workplace settings. These studies are discussed in Section B below.

The age-, gender-, and smoking-specific lung cancer mortality data involve a rather complicated derivation. Since there is no central cancer registry in Ontario, we use Statistics Canada data on lung cancer mortality in Canada for 1978. These data are age- and gender-specific.

We further assume that the current mortality rates from lung cancer per 100,000 population will persist into the future. Whether or not the actual mortality rates in fact remain constant depends on several factors, including: the likelihood of improving the prognosis for lung cancer victims, the prevalence of environmental carcinogens, and smoking habits within the general population. Smoking habits are currently changing. For example, the percentage of females who smoke is increasing.

These lung cancer mortality data are modified so that the death rates would be smoking-specific (i.e., reflect the actual probabilities of survival experienced by smokers and non-smokers). This is accomplished by using the data furnished by the Health Promotion Directorate of Health and Welfare Canada on Canadian smoking patterns for the general population and weighting these proportions by a smoking lung cancer risk factor derived from the study by Richard Doll and Richard Peto of cancer rates among British doctors.<sup>7</sup> The information on Canadian smoking patterns is age- and gender-specific, while a risk constant derived from Doll and Peto of 10.4 is used for all ages and both sexes. This factor is the relative risk

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<sup>7</sup>Richard Doll and Richard Peto, "Mortality in Relation to Smoking: 20 Years' Observations on Male British Doctors," *British Medical Journal* 2:6051 (25 December 1976): 1525-1536.

ratio that is obtained when lung cancer rates for smokers and non-smokers are compared.

Implicit in the calculation of our smoking-specific mortality rates is the assumption that all excess risks entailed by smoking at a certain age accrue only to those members who are still smoking at that age. This means that smokers who stop smoking, for example at age 50, will experience no increment in the lung cancer risk above that of non-smokers at later ages. To provide a more precise measure would require data on the percentages of smoking quitters in the general population, the age at which these occur, and the decrease in risk enjoyed by smoking quitters. Unfortunately, data of this specificity are not available. However, Doll and Peto have speculated that the decrease in risk from smoking quitters could be quite large. This hypothesis, if true, would enhance the validity of our model.

In order to account for the level of natural removal occurring during the life of an exposed population, survival rates were derived from life tables which were gender- and smoking-specific. The life tables were developed by using standard actuarial techniques and data on Canadian mortality rates for 1978. As for the lung cancer calculation, the general mortality rates were rendered smoking-specific by combining the percentages of smokers and non-smokers in the population with the relative risk of death for all causes entailed by smoking. These relative risk values are shown in Table 1.

Once modified, the mortality data are inserted into our model which calculates life expectancy tables. These tables determine, for a given population and mortality experience, the cumulative probability of surviving to a certain age and the amount of life-years lost for premature mortality. Because the data used to generate the tables are smoking-, gender-, and age-specific, so obviously are the survival rates. See Tables 2 and 3. These survival trends were assumed to remain constant for the lifespan of the exposed population.

Figure 7 summarizes the steps in calculating the risk of lung cancer mortality from asbestos exposure using the model just described.

## **D. Mesothelioma Dose-Response Function**

Mesothelioma, in contrast to lung cancer, is a disease that is related almost exclusively to asbestos exposure. Mesothelioma is a cancer of the tissue covering the lungs and abdominal cavity (pleura and peritoneum). As with lung cancer, the prognosis for victims who develop mesothelioma is extremely bleak.

**Table 1**  
**Relative Risk of Mortality for Smokers**

<b>Age</b>	<b>Relative Risk of Death from All Causes</b>
35-39	1.49
40-44	2.16
45-49	2.60
50-54	2.02
55-59	1.99
60-64	1.93
65-69	2.20
70-74	1.57
75-79	1.28

SOURCE: Adapted from: Richard Doll and Richard Peto, "Mortality in Relation to Smoking: 20 Years' Observations on Male British Doctors," *British Medical Journal* 2:6051 (25 December 1976): 1536 (Table XIII).

Table 2  
Cumulative Survival Probabilities and Expected Life-Years Remaining for Smokers and Non-Smokers: Male

Interval	Smokers		Non-Smokers	
	Cumulative Survival Probability	Life-Years Remaining	Cumulative Survival Probability	Life-Years Remaining
20-24	1.000000	48.37	1.000000	55.01
25-29	0.990884	43.79	0.990884	50.50
30-34	0.983680	39.04	0.983680	45.85
35-39	0.9762299	34.47	0.9762299	41.18
40-44	0.9638647	29.78	0.9679144	36.50
45-49	0.9416987	25.42	0.9575451	31.87
50-54	0.904413	21.37	0.9427836	27.33
55-59	0.8486289	17.61	0.9135403	23.12
60-64	0.7686718	14.18	0.8692492	19.17
65-69	0.6607534	11.09	0.8038025	15.53
70-74	0.4697653	9.57	0.7088276	12.27
75-79	0.3339815	7.43	0.5711107	9.63
80-84	0.2129687	5.27	0.4027666	7.61

Table 3  
Cumulative Survival Probabilities and Expected Life-Years Remaining for Smokers and Non-Smokers: Female

Interval	Smokers		Non-Smokers	
	Cumulative Survival Probability	Life-Years Remaining	Cumulative Survival Probability	Life-Years Remaining
20-24	1.00000	55.25	1.00000	61.12
25-29	0.99727	50.39	0.99727	56.28
30-34	0.99456	45.52	0.99456	51.93
35-39	0.99107	40.67	0.99107	46.60
40-44	0.98423	35.94	0.98648	41.81
45-49	0.97187	31.36	0.98072	37.04
50-54	0.94873	27.07	0.97167	32.36
55-59	0.91640	22.94	0.95514	27.98
60-64	0.87138	18.99	0.93127	23.53
65-69	0.80543	15.34	0.89407	19.40
70-74	0.68988	12.49	0.83339	13.63
75-79	0.57112	9.57	0.73907	12.31
80-84	0.44048	6.67	0.60360	9.51
85 +	0.25471	4.70	0.42801	7.39

**Figure 7****Steps in Calculating Excess Lung Cancer Mortality from Asbestos Exposure**

- (i) Derive proportionality constant (C) which links excess relative risk of lung cancer with cumulative exposure.
- (ii) Select a duration and fibre intensity for a hypothetical workforce.
- (iii) Multiply duration by fibre intensity to obtain cumulative exposure.
- (iv) Multiply cumulative exposure for workforce by proportionality constant (C) to determine the excess relative risk experienced in each quinquennium.
- (v) Multiply the excess relative risk value by smoking-, age-, and gender-specific background lung cancer rates in each quinquennium to determine excess lung cancer rate.
- (vi) Multiply the excess lung cancer rate in each quinquennium by the probability of being alive in that age interval.
- (vii) For all age intervals, multiply the excess lung cancer rate (scaled to survival) by the number of workers exposed to asbestos. In determining the number of exposed workers alive in each quinquennium, take into account previous mortality from asbestos-related death.
- (viii) Sum mortality over all periods.

## D.1 Response Metric

The methodology employed for predicting the risk of mesothelioma mortality for an exposed population is different from that used to calculate lung cancer mortality. This difference arises from the absence of any relationship between the asbestos-related mesothelioma rate and the extremely low background rate of mesothelioma.<sup>8</sup> It is, therefore, not possible to calculate the mesothelioma rate as some multiple of the background rate. We will instead use mortality rates per year as the response metric for mesothelioma rather than relative or excess risk.

## D.2 The Effect of Time Since First Exposure on Mortality

Another difference between lung cancer and mesothelioma dose-response functions concerns the pattern of risk after first exposure. Unlike the relative risk of lung cancer, which is solely a function of cumulative exposure, Mr. Julian Peto has found that the mesothelioma mortality rate is a function of not only the dose and duration of asbestos exposure, but also the time since first exposure.<sup>9</sup> As time passes after an initial exposure, the chance of death from mesothelioma occurring increases. Imputing consideration of time since first exposure into a risk equation causes early exposure to be weighted more heavily than subsequent exposure.

The relation between mesothelioma and time since first exposure has been found to be a power function; that is, if mesothelioma mortality for a population exposed to asbestos is plotted on a logarithmic scale against time since first exposure, a linear function is observed. Mr. Peto has found that the value of this exponent is between 3 and 4.<sup>10</sup> According to Mr. Peto, the added risk of mesothelioma mortality entailed by one day's exposure to asbestos at a given intensity is proportional to time since first exposure cubed. Integrating the risk curves over continuous exposure generates a risk curve depending on time since first exposure to the fourth. For intermediate exposure, that is, when time since first exposure is greater than duration, mortality is proportional to  $T^4 - (T-D)^4$ : where T is equal to time since first exposure and D equals duration of exposure.<sup>11</sup>

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<sup>8</sup>Letter and attachments from Mr. Julian Peto, Imperial Cancer Research Fund, University of Oxford, Oxford, England to the Royal Commission on Asbestos, 21 September 1983.

<sup>9</sup>Julian Peto, "Dose And Time Relationships for Lung Cancer and Mesothelioma in Relation to Smoking and Asbestos Exposure," in *Zur Beurteilung der Krebsgefahren durch Asbest* [Proceedings of the Bundesgesundheitsamt Asbestos Symposium], Berlin: February 1982, bga Schriften, MMV Medizin Verlag München, in press, 1983, p. 2.

<sup>10</sup>Ibid., p. 3.

<sup>11</sup>Ibid., p. 4.

Figure 8 represents this relationship in diagrammatic form. Here, each curve A through E shows the separate effects of successive occurrences of exposure to asbestos on the risk of mesothelioma mortality. Any point on an incidence curve represents the risk of mesothelioma at a specific time since onset of exposure for a given exposure interval. The risk of developing mesothelioma from the cumulative exposure is the sum of these curves. This total risk increases at a decreasing rate with further exposure, because the contribution to total mesothelioma incidence at time (T) of the most recent exposure curve is almost insignificant in comparison to the impact of the preceding curves. With risk growing at an increasing rate as a function of time since first exposure, in time the risk caused by early exposure is so high that the impact of subsequent exposure is dwarfed in comparison.

### **D.3 Pattern of Mesothelioma Dose-Response Function Independent of Age and Underlying Fibre Type**

In our model, the pattern of mesothelioma risk is also independent of age at first exposure. Figure 9 shows the pattern of mesothelioma mortality of workers exposed at different ages plotted against time since first exposure. This exercise reveals parallel behaviour in the mortality pattern regardless of age at first exposure. For our purposes, it is important that a population exposed to asbestos in their mid-50s will not experience high rates of mesothelioma mortality. This is because mortality from mesothelioma will not become significantly elevated until at least 20 years after first exposure. In contrast, since the lung cancer risk function is dependent upon background lung cancer rates and these rates are highest for an elderly population, a population first exposed in their 50s will experience high rates of excess lung cancer once the delay period has been surpassed.

Mr. Julian Peto has also found that the pattern of mesothelioma risk predicted by the equation  $T^4 - (T-D)^4$  fits the pattern of mesothelioma mortality across a number of epidemiological studies *each with different underlying fibre types and fibre dimensions*.<sup>12</sup> Yet, while the pattern of mesothelioma risk is similar throughout a range of different studies, the absolute values of the pattern (i.e., the vertical intercept of the curve on logarithmic paper) may vary in accordance with fibre type and fibre process.

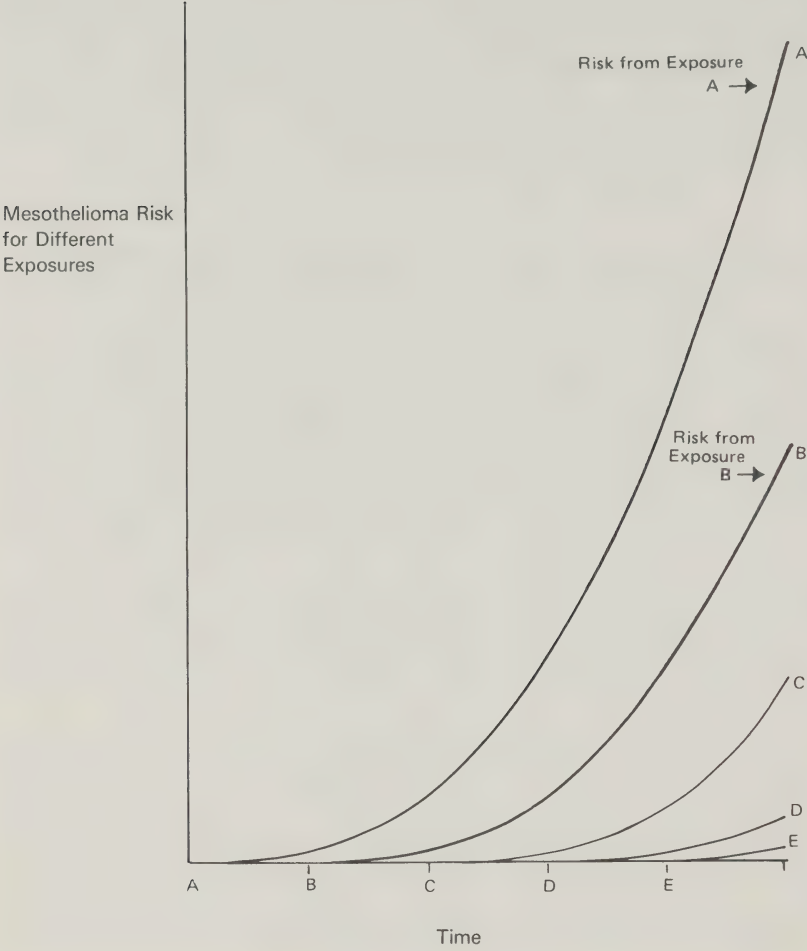
### **D.4 Mesothelioma Mortality as a Function of Time**

Whether the mesothelioma risk continues to increase as a power function of time after 50 years of follow-up is not clear from existing studies.

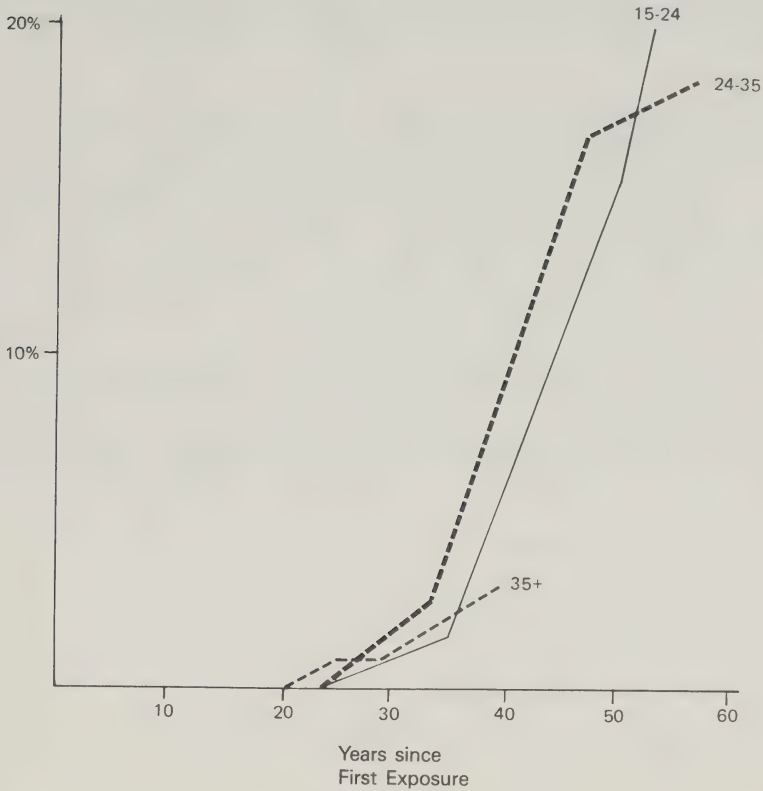
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<sup>12</sup>Ibid., p. 3.

**Figure 8**  
**Risk of Mesothelioma Mortality Entailed by Asbestos Exposures**  
**as a Function of Time Since First Exposure**



**Figure 9**  
**Cumulative Risk of Mesothelioma Mortality**



SOURCE: Ontario, Royal Commission on Asbestos, Exhibit II-37, Tab 12, in RCA Transcript of Public Hearings, Evidence of Mr. Julian Peto, 29 July 1981, Volume no. 25(A), pp. 10ff; Mr. Julian Peto, Assorted Transparencies. (Mimeographed.) Based on data from Irving J. Selikoff, E. Cuyler Hammond, and Herbert Seidman, "Mortality Experience of Insulation Workers in the United States and Canada, 1943-1976," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 91-116.

Determining the behaviour of the mesothelioma risk function well after the onset of exposure is confounded by the same data limitations which hinder our understanding of the behaviour of the lung cancer function after lengthy follow-up. Again, we are reluctant to introduce in our model any trail-off for mesothelioma mortality after extensive follow-up because of the dearth of robust data which would enable us to model accurately this effect.

## D.5 Presentation of Model

The relationships discussed above are integrated into Mr. Peto's mesothelioma model presented below:

$$MI(a) = K * [T^4 - (T-D)^4] * FCC * NOW * S(a) / S(A),$$

Where:

$MI(a)$  = number of mesothelioma deaths per year at age  $a$  in a cohort of size  $NOW$  resulting from asbestos exposure beginning at age  $A$ ;

$K$  = a proportionality constant derived from epidemiological studies which relates the risk of mesothelioma mortality to the intensity and duration of asbestos exposure;

$T$  = time since first exposure =  $a - A$ ;

$D$  = duration of exposure to asbestos;

$FCC$  = fibre intensity in  $f/cc$ ;

$NOW$  = number of workers exposed;

$S(a)$ ,  $S(A)$  = cumulative probability of survival to ages  $(a)$  and  $(A)$  respectively.

The age-specific incidence of mesothelioma is more or less independent of smoking, but as non-smokers live longer than smokers it is still necessary to calculate separate life expectancy tables for smokers and non-smokers in the same way as for lung cancer. Non-smokers run a greater risk of developing mesothelioma than smokers, as a higher proportion survive to old age, when mesothelioma mortality is greatest. These life expectancy tables will be generated using the same data and techniques discussed with reference to lung cancer.

Figure 10 summarizes the steps in calculating the risk of mesothelioma mortality using the model just described.

## E. Calculation of Mortality and Total Life-Years Lost

With the risk equations for lung cancer and mesothelioma that have

**Figure 10**  
**Steps in Calculating Mesothelioma Mortality**  
**from Asbestos Exposure**

- (i) Derive proportionality constant (K) which links rate of mesothelioma mortality with intensity and duration of exposure and time since first exposure.
- (ii) Select a duration and fibre intensity for a hypothetical workforce.
- (iii) For each quinquennium following exposure, multiply K by  $[T^4 - (T-D)^4]$  FCC to determine rate of mesothelioma mortality.
- (iv) Multiply gender-, smoking-, and age-specific probability of being alive in each interval by number of exposed workers. Take into account removal of workers in previous interval by asbestos-related death.
- (v) Multiply number of workers alive in each quinquennium by 5 years to determine total number of man-years in interval.
- (vi) Multiply total number of man-years in interval by mesothelioma rate previously determined, to arrive at total mortality for interval.
- (vii) Sum mortality over all periods.

been developed, we can now proceed to calculate both the total lifelong mortality risk and life-years lost from premature mortality for a group of asbestos workers. All that is required is that we establish a cohort of workers and specify their age, sex, and smoking characteristics along with the intensity and duration of asbestos exposure that they experience. From these data, the total number of deaths due to asbestos that will occur in the cohort is calculated by summing the numbers in each year [IE(a) and MI(a) in the equations in sections C.8 and D.5 of this Appendix] for each year of age from first exposure at age A to age 80. We selected 80 years for the outer boundary of the calculation because few epidemiological studies contained observations on the mortality experienced by workers surviving beyond this age.

This model includes the ability to determine the number of life-years lost from premature death. Once the total number of deaths due to asbestos at each age is known, this value is multiplied by the expected life-years remaining for this age. This index was developed from the survival probabilities outlined previously and displayed in Tables 2 and 3. Again, this calculation is executed for each year from first exposure at age A to age 80 and the results summed.

One last feature of our model is our removal of those population members who are expected to suffer an asbestos-related death in a certain quinquennium. This ensures that a worker who suffers early mortality will not be considered a part of the surviving cohort and thus will not be counted as dying twice from an asbestos-related disease.

## **Section 2: Methodologic Review and Summary of Epidemiological Studies of Asbestos Exposure**

Below we review the quality of seven epidemiological studies and then derive proportionality constants which will be inserted into our dose-response functions. Six of these studies are characterized by data on the conditions and intensity of exposure which were obtained for the workplace in which the cohort was exposed. The other study contains no exposure data, but can be supplemented by exposure estimates based on dust measurements in other places at other times. These data are used as surrogates for the experience of the cohort under study. We will first examine the six studies which contain environmental data from the workplace at which the cohort was exposed.

## A. Review of Six Epidemiological Studies with Environmental Data

While there have been a multitude of mortality studies of asbestos workers, only six studies have been published which have associated environmental data of “reasonable” quality. None of these is entirely satisfactory in its own right and together they do not provide a precise estimate of the relationship between asbestos exposure and cancer risk. Thus, even though asbestos was “prescribed” in the United Kingdom in 1931 (admittedly because of asbestosis, not cancer), we must resign ourselves to the fact that the data relating dose to risk were still not definitive in 1983.

### A.1 Review Technique

This section will briefly review the epidemiological quality of the six key studies and provide a summary of their methodology and results. The principal authors of the six studies are given below, along with brief identifying outlines of their work:

- (i) J. Corbett McDonald et al. [hereafter J.C. McDonald] — study of miners and millers in Quebec;<sup>13</sup>
- (ii) Vivian L. Henderson and Philip E. Enterline [hereafter Enterline] — study of retired asbestos products workers of the Johns-Manville Corporation;<sup>14</sup>
- (iii) Julian Peto (et al.) [hereafter Peto] — study of asbestos textile factory workers at Rochdale, England;<sup>15</sup>

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<sup>13</sup>J. Corbett McDonald et al., “Mortality in the Chrysotile Asbestos Mines and Mills of Quebec,” *Archives of Environmental Health* 22 (June 1971): 677–686. See also, J. Corbett McDonald et al., “Dust Exposure and Mortality in Chrysotile Mining, 1910–75,” *British Journal of Industrial Medicine* 37 (1980): 11–24.

<sup>14</sup>Philip E. Enterline, Pierre DeCoulle, and Vivian L. Henderson, “Respiratory Cancer in Relation to Occupational Exposures Among Retired Asbestos Workers,” *British Journal of Industrial Medicine* 30:1 (January 1973): 162–166. See also, Vivian L. Henderson and Philip E. Enterline, “Asbestos Exposure: Factors Associated with Excess Cancer and Respiratory Disease Mortality,” *Annals of the New York Academy of Sciences* 330 (14 December 1979): 117–126.

<sup>15</sup>Julian Peto, “Lung Cancer Mortality in Relation to Measured Dust Levels in an Asbestos Textile Factory,” in *Biological Effects of Mineral Fibres*, vol. 2, ed. J.C. Wagner, IARC Scientific Publications, no. 30 (Lyon, France: International Agency for Research on Cancer, 1980), pp. 829–836; and Julian Peto et al., “A Mortality Study Among Workers in an English Asbestos Factory,” *British Journal of Industrial Medicine* 34 (1977): 169–173. See also, Geoffrey Berry et al., “Asbestosis: A Study of Dose-Response Relationships in an Asbestos Textile Factory,” *British Journal of Industrial Medicine* 36:2 (May 1979): 98–112; J.F. Knox et al., “Mortality from Lung Cancer and Other Causes Among Workers in an Asbestos Textile Factory,” *British Journal of Industrial Medicine* 25 (1968): 293–303.

(iv) John M. Dement et al. [hereafter Dement] — study of asbestos textile factory workers at Charleston, North Carolina;<sup>16</sup>

(v) Geoffrey Berry and Muriel L. Newhouse [hereafter Berry] — study of the Ferodo friction materials factory workers at Derbyshire, England;<sup>17</sup>

(vi) Murray M. Finkelstein — study of asbestos-cement workers at Scarborough, Ontario.<sup>18</sup>

All six are conventional historical prospective studies. We have reviewed them methodologically in four areas: (i) study cohort; (ii) quantification of exposure; (iii) mortality ascertainment; and (iv) analysis. Each of these was subdivided into a number of features and a maximum numerical score assigned reflecting the perceived importance of that feature to overall methodologic quality. Finally, each study was assessed with respect to each feature and given a score (up to a maximum for that feature) to reflect how good the study was in this area. These scores are then summed up for the overall assessment of methodologic strength.

The results of this review are summarized in Table 4, and the methodologic details of each study are summarized in Table 5.

## A.2 Methodologic Review

### (a) Study Cohort

*Selection Method (5 points)* — We believe that the selection method least likely to result in bias is to select study subjects as they are first hired by the industry (an inception cohort), as opposed to cross-sectional censuses at one or more points in time. The Quebec study is clearly the best in this regard as the investigators identified everyone who had ever worked for one month or more and who was born between 1891 and 1920. The Rochdale and Charleston studies have adopted the more usual sampling procedure of sampling arriving employees but limited to those most recently hired when employee records were adequate. The study by Dr. Enterline of Manville employees selected study subjects at the point of retirement at age 65 and thus must be viewed much more skeptically because of intervening mor-

<sup>16</sup>John M. Dement et al., "Estimates of Dose-Response for Respiratory Cancer Among Chrysotile Asbestos Textile Workers," *Annals of Occupational Hygiene* 26:1-4 (1982): 869-887.

<sup>17</sup>Geoffrey Berry and Muriel L. Newhouse, "Mortality of Workers Manufacturing Friction Materials Using Asbestos," *British Journal of Industrial Medicine* 40:1 (February 1983): 1-7.

<sup>18</sup>Murray M. Finkelstein, "Mortality Among Employees of an Ontario Asbestos-Cement Factory," Toronto, Ontario Ministry of Labour, February 1983, revised September 1983. (Mimeographed.)

Table 4  
Methodologic Assessment

Study Feature	Points	J.C. McDonald	Enterline	Peto	Dement	Berry	Finkelstein
<b>A. Study Cohort</b>							
Selection method	(5)	****	*	****	***	****	****
Inclusion/Exclusion	(2)	**	*	*	**	**	**
Sample/Complete	(1)	*	*	*	*	*	*
Size	(3)	***	**	*	*	**	*
Subtotal	(11)	11	5	7	8	11	9
<b>B. Quantification of Exposure</b>							
Work history detail	(3)	***	**	***	***	*	**
Extent of industrial hygiene data	(5)	**	*	****	***	**	**
Quality of measures	(5)	*	*	****	***	**	*
Smoking data	(3)	***	*	*	**	*	*
Subtotal	(16)	9	5	11	11	5	5
<b>C. Mortality Ascertainment</b>							
Quality of technique	(5)	*****	****	****	***	****	***
Completeness	(5)	****	****	***	***	****	***
Availability of certificates	(3)	***	**	***	**	***	***
Length of follow-up	(2)	**	**	**	**	**	**
Subtotal	(15)	14	12	12	11	14	13
<b>D. Analyses</b>							
Suitability of external control	(3)	***	**	**	*	**	***
Internal comparison	(2)	**	**	**	**	**	**
Latency	(2)	**	**	**	**	*	**
Statistics	(2)	*	*	*	*	**	*
Exposure gradient	(2)	**	**	**	**	**	*
Bias discussion	(1)	*	*	*	*	*	*
Subtotal	(12)	11	8	10	7	10	10
TOTAL	(53)	45	30	40	37	40	37

Table 5  
Methodologic Summary

Study Feature	J. C. McDonald	Enterline	Peto	Dement	Berry	Finkelstein
<b>A. Study Cohort</b>						
Selection method and criteria	All workers ≥ 1 month mines/mills Born 1891-1920	All Manville pensioners 1941-1967 (pro- duction workers only)	Hired 1933 or later ≥ 10 years service by 1972	White males ≥ 6 months service (≥ 1 month between 1/1/1940 and 31/12/1965)	All employees hired between 1941 and 1960	All workers > 1 year of employ- ment between 1948 and 1960
Size (dead)	11,379 (4,547)	1,075 (781)	679 (239)	768 (191)	13,460 (2,173)	535 (138)
Fibre type	Chrysotile	Chrysotile/ amphibole	Chrysotile/ some crocidolite	Chrysotile	Chrysotile/ some crocidolite	Chrysotile/ crocidolite
<b>B. Quantification of Exposure</b>						
Individual work histories	Yes	Yes	Yes	Yes	No	Yes
Industrial hygiene sampling method	Midget Impinger	Midget Impinger	Casella TP, high vol., membrane filter	Midget Impinger membrane filter	Membrane Filter simulations	Midget Impinger Membrane filter
Number of samples	4,152	Not reported	Routine since 1951	5,952	Routine since 1967	Routine since 1969
<b>C. Ascertainment of Mortality</b>						
Technique	Individual follow-up	SSA match and company records	NHS Central Registry	SSA and local agencies	NHS Central Registry	Personal follow- up and computer searches
Completeness	98% (post 1935)	Not reported	94%	97%	96%	94%
Available death certificates	97%	96%	Not reported	93%	100%	99.1%
<b>D. Analyses</b>						
Comparative population	Quebec	U. S.	U. K.	U. S.	England	Ontario
Latency assumed (since last exposure)	20 years	not used	20 years for dose-response	15 years	10 years	20 years
Exposure metric used for dose-response	mppcf	mppcf	f/cc-yrs	f/cc-yrs	f/cc-yrs	f/cc-yrs

tality. The resulting survival cohort is much more difficult to interpret. Mr. Berry studied all workers joining the company from 1940 onwards, when a new work history system was implemented. Recent hirings (after 1960) have not been included because of the relatively short time since first exposure. Dr. Finkelstein studied all employees since the plant's opening in 1948 who had accumulated one year or more of service and were employed initially prior to 1960, again for latency reasons.

*Inclusion/Exclusion Criteria (2 points)* — All studies, except the Berry study, applied a minimum duration of service criterion. They ranged from one month for the Quebec study to 10 years for Rochdale, with the Charleston and the Scarborough plants in between at 6 months and one year respectively. The Manville retirees study has an implied criterion since a man, to be included, must have been receiving a pension. From data in the paper the minimum duration of service would appear to be 3 years. Since there is particular interest in the dose-response function at low doses, a higher rating is assigned to studies that include exposures of short duration or low intensity such that the cumulative dose includes low as well as moderate or high levels.

*Sample/Complete Enumeration (1 point)* — All six studies included all eligible subjects as opposed to studying a sample and thus are equivalent in terms of sampling procedure.

*Size (3 points)* — The power of a mortality study to detect excess risk is directly related to the size of the study and in particular to the expected number of asbestos-related deaths. Mr. Berry studied 13,460 subjects, of whom 2,173 died during the follow-up period. This was the biggest mortality study of the six reviewed, although the Quebec study had more deaths with over 11,000 study subjects and 4,500 observed deaths. The Scarborough study (535 subjects), by contrast, was the smallest of the six. This is probably the single most important criticism, and yet the study does provide surprisingly extensive data on the risk of mesothelioma. While the other three studies are of the same order of magnitude in terms of size, the older cohort of Manville retirees had 4 times as many observed deaths as either Rochdale or Charleston, and is thus judged to be more powerful.

## **(b) Quantification of Exposure**

*Work History Detail (3 points)* — The J.C. McDonald, Peto, Enterline, and Dement studies all had access to the individual work history of each study subject. While little information was provided as to the level of detail, all appeared comparable in their ability to describe where each subject worked. Even though individual job titles might be quite precise, each study has grouped them into dustiness "categories" for dose-response purposes. Dr. J.C. McDonald used thirteen categories in computing dose, while

Dr. Enterline used six. Dr. Dement and Mr. Peto both used sixteen categories.

Insofar as the Berry and Finkelstein studies are concerned, neither study has provided much background information on the degree of detail available in the work histories. There is a clear indication that this was a problem in the Berry study because the information was by cost centre rather than by job title. This necessitated a fair degree of judgement when interpreting a history. Thus, when Mr. Berry came to compute cumulative exposures he had to rely on company personnel to "guesstimate" where subjects had actually worked. Dr. Finkelstein provided little description other than saying that good quality individual histories were available. We are not told how many jobs had individual exposure estimates associated with them.

*Extent of Industrial Hygiene Data (5 points)* — Although quantity is no substitute for quality, the extent of industrial hygiene data in terms of the number of measurements taken and the years in which they were done is important.

While Dr. J.C. McDonald stated that over 4,000 midjet impinger readings were available from annual surveys in the period 1949–1966, very few of these were in underground mines or open cast pits where the bulk of the cohort was exposed. The Dement study at Charleston had over 5,000 individual measurements in the plant during the period 1960–1975, but less than 200 measurements in each of the periods 1930–1945 and 1945–1960. However, this was judged to be a model plant by North American standards and, as such, probably has the best industrial hygiene data of any asbestos processor in the United States. The Rochdale study plant in the United Kingdom had routine monitoring from 1951 onwards and some *ad hoc* surveys before this date. While none of the publications indicated the exact number of measurements available, the plant had probably had the best U.K. data; hence its choice for the asbestosis study which was the basis for the 2 f/cc U.K. standard. Based on published descriptions, the Manville study would appear to have had much less exposure data than the Rochdale, Charleston, and Quebec studies.

The Berry study indicated that "routine" membrane filter measures were available since 1967 and personal sampling was introduced in 1968. Pre-1967 conditions were estimated by running the plant for a short period with equivalent pre-1967 ventilation levels and old production techniques. This is a valuable endeavour, but we are not told what data were collected and how long the simulation ran. Dr. Finkelstein listed dates of *ad hoc* government surveys and indicated that routine impinger data were available from 1960 onwards, and personal membrane filter estimates, from 1969. The extent of the data was not indicated. The calculations for dose-response purposes were based on 1969 and 1970 data, plus some crude

assumptions about magnitudes of dustiness increases prior to 1969. No side-by-side impinger/membrane filter studies seemed to be available, so, unlike Dr. Dement's study, earlier impinger results have not been formally "converted" to equivalent fibre counts. Dr. Finkelstein made the point that the crude assumptions seemed to be in line with the trends in impinger counts, however.

Until concrete evidence shows the contrary, we conclude that the Finkelstein exposure data are about on a par with those of the Enterline study, and that the Berry study has slightly less extensive data than the Dement and Peto studies.

*Quality of Industrial Hygiene Measures (5 points)* — The quality of the industrial hygiene data is basically related to whether fibres have been measured and when the change from counting particles to fibres took place. The J.C. McDonald and Enterline studies are not strong in this regard since almost all of their industrial hygiene data were derived from the midget impinger as particle counts. Dr. J.C. McDonald did have some high volume data available for the mines in a survey done in 1968. Recent side-by-side surveys have been conducted in Quebec to try to develop a conversion factor for midget impinger to membrane filter fibre counts, but, because of the low efficiency with which the midget impinger collects fibres, these conversions have proved very unreliable. Both Dr. J.C. McDonald and Dr. Enterline thus continue to analyze dose-response relationships in terms of million particles per cubic foot (mppcf).

The switch to fibre counting, initially with long-running thermal precipitators and then membrane filters, commenced in 1961 at Rochdale, prior to which time Casella thermal precipitators were used to produce particle counts. At Charleston, midget impingers were used until 1971 with membrane filters introduced in 1965 and used solely from 1971 onwards. A total of 120 paired impinger/membrane filter samples were available, together with 986 measures of either impinger or membrane filter type taken during concurrent periods but not side by side.

The relationship between particle counts and fibre counts was studied carefully by Dr. Dement. The paired observations yielded a strongly significant correlation of 0.58 and indicated that 2.9 f/cc longer than 5 microns is equivalent to a particle count of 1 mppcf (the 95% confidence interval being 2.4 to 3.5). There was some evidence to suggest that the preparation area had a higher concentration of fibres. By comparison, the 986 concurrent samples yielded a conversion factor of 2.5 (the 95% confidence interval being 2.1 to 3.0) for most areas of the plant. The exception was, again, preparation which produced a conversion factor of 7.8 f/cc for each 1 mppcf. Subsequent calculations of dose-response relationships used conversions of 8 for preparation and 3 elsewhere in the plant.

We have dealt with this issue in some detail because it is one of the most contentious points raised in criticism of Dr. Dement's analysis. It is widely believed by experts that there should be a higher ratio of fibre to non-fibre particles in a textile mill than, say, in an asbestos mine or mill because processing is aimed at producing pure fibre. However, these conversion factors produced by Dr. Dement were almost equivalent to those arrived at by Dr. Graham W. Gibbs for the Quebec mines and a little lower than those for the Quebec mills. Thus, while somewhat lower than expected, Dr. Dement's values were derived from extensive data using valid statistical procedures and, in our view, must be taken at face value. Incidentally, early Casella thermal precipitator data at Rochdale were converted to fibre counts with a conversion factor which averaged at only 1 mppcf = 1.0 f/cc. The combination of earlier membrane filter data, plus measurements under simulated conditions, indicates that industrial hygiene data in the Berry study are of better quality than those in the Finkelstein study. Both would seem poorer in quality than the Dement data, which are in turn inferior to the Peto Rochdale data.

*Smoking Data (3 points)* — Clearly, with lung cancer as an outcome, smoking is an important confounding influence. Ideally, studies should have data on the smoking histories of each subject and an analysis of the effects of asbestos exposure conducted separately within smoking status groups (smoker, non-smoker, ex-smoker, etc.). An alternative, although a less satisfactory approach, is to demonstrate, usually on a sample basis, that the prevalence of smoking in study subjects is similar to the comparison population.

Of the six studies, the best smoking data by far were available in Dr. J.C. McDonald's Quebec study from a 1970 survey of live subjects and by interviews with relatives of men who had died prior to 1950. Dr. Dement's study at Charleston had smoking prevalence data available from a public health survey of the plant in 1964 and 1971. These rates were very close to the overall rates for U.S. white males in the same period. Dr. Enterline claimed to have smoking data from Manville's company records on about 25% of his cohort, of whom 77% were or had been smokers, again in line with national rates. Mr. Peto's study at Rochdale had very little to say about smoking except in relation to a small case-control type sub-analysis. The Berry study of the Ferodo plant at Derbyshire did not mention smoking data as being available. Dr. Finkelstein had smoking data on about 50% of his subjects at Scarborough.

### (c) Mortality Ascertainment

*Quality of Technique (5 points)* — Dr. J.C. McDonald used the "best" technique of individually tracing each subject to locate the man or his relatives. Mr. Peto used the U.K. National Health Service (NHS) registry of a patient's current physician, which is highly reliable and con-

stantly updated for mortality. Dr. Dement used primarily the files of the U.S. Social Security Agency (SSA) which records insurance payments to and from workers. Death information is thought to be incomplete in this file, but Dr. Dement complemented this search with local tax and postal information. Dr. Enterline used company records plus SSA files, which for a retired study group receiving a pension should be quite good. Mr. Berry determined the current status of his cohort by using the NHS physician register, which is of proven reliability. Dr. Finkelstein used a variety of techniques which seemed to involve personal follow-up but also included computer record linkage.

*Completeness (5 points)* — The five studies which provided figures on the success of follow-up all achieved well over 90%. The Rochdale and Scarborough studies were poorest with 94% each; and the Derbyshire (Ferodo), Charleston, and Quebec studies attained 96%, 97%, and 98% (after 1935) respectively. The study of Manville plants by Dr. Enterline did not provide a comparative figure but claimed the follow-up was perfect because the company would know if a pensioner had died. This seems a reasonable statement, but it is not clear if corroborative evidence was sought.

*Availability of Death Certificates (3 points)* — In the United Kingdom, death certificates are public documents stored centrally in Somerset House in London and are thus routinely available for study. In the U.S. and Canada, original certificates are stored in the administrative centre of the state or province of residence. This often makes it difficult to find certificates. While Dr. J.C. McDonald located 97% of death certificates, Dr. Enterline found 96%, and Dr. Dement, only 93%. The unknown causes of death cannot be included in cause-specific analyses and may bias the remaining causes of death if the likelihood of not finding a certificate varies with cause (perhaps lower for a compensable disease). Mr. Berry claimed that death certificates were available for all subjects found to have died, while Dr. Finkelstein located certificates for all but one deceased.

*Length of Follow-up (2 points)* — All six studies would appear to have had adequately long follow-up periods, usually from the 1930s to the mid-1970s. All had enough data to handle appropriately the issue of latency.

#### (d) Analysis

*Suitability of the External Control (3 points)* — The J.C. McDonald study used the Quebec mortality rates as the basis of its standard mortality ratio (SMR) calculations. Since two sites were involved and Quebec residents tend to stay in the province, this was a suitable choice. The Enterline study used all U.S. white males for comparison purposes. Again, since a number of plants in different locations were involved, this would

seem reasonable compared to the alternative of a mix of states. The Peto study used the U.K. national rates in the Rochdale study and the Dement study used mortality rates from U.S. white males. Dr. Dement has come under some criticism for his choice of comparative population primarily because, in attempting an honest methodologic discussion of the main alternatives, he reported higher than average lung cancer mortality rates in the county around the asbestos plant. He attributed this to the presence of a large naval shipyard in the same county providing an alternative source of asbestos exposure especially during the war years when 29,000 men were employed.

Dr. Dement's decision not to use the local county rates is entirely appropriate; he might have used the state data instead, but since the lung cancer mortality rate in the state is virtually the same as the national rate, the latter is to be preferred. However, of more concern than the choice of external control is the possibility of contamination from the shipyard exposure prior to or after becoming a study subject by working at the asbestos textile factory.

Mr. Berry used mortality rates derived from the whole of England and Wales in calculating SMRs, whereas Dr. Finkelstein use the Ontario population. The latter approach would appear to offer a slightly better socio-economic matching.

*Internal Comparison (2 points)* — The Quebec, Rochdale, Derbyshire (Ferodo), and Scarborough studies all complemented the usual analysis of SMRs calculated with reference to an external control by an internal comparison. Dr. J.C. McDonald, Mr. Peto, and Mr. Berry did this by a case-control approach in which cases of lung cancer were matched with controls chosen from other study subjects alive when the case died. The comparison of exposure levels between cases and controls then forms the basis of the estimation of risk. Dr. Finkelstein used as controls a group of 87 men who worked in a rock wool process at the same plant.

*Latency (2 points)* — All authors were aware of the need to allow for an appropriately long latency period in calculating cancer risks from asbestos. Dr. J.C. McDonald and Dr. Finkelstein looked only at rates 20 years or more since first exposure; Dr. Dement chose 15 years; and Mr. Berry, 10. Mr. Peto had years since first exposure as a tabulated variable. Dr. Enterline did not specify a figure, but, presumably, since his study subjects had reached retirement, they had already got beyond the latency period. A specific verification of this would have been useful.

*Statistics (2 points)* — The Quebec, Rochdale, Manville, and Charleston studies did a comparable job at statistical analysis. None routinely reported exact values or, more importantly, provided confidence intervals on estimated risks. The J.C. McDonald study, unlike other

studies, did not provide tests of significance on SMRs on philosophical grounds (presumably because the study group is viewed as a finite population in its own right and thus has no sampling variation). This study did, however, provide tests for dose-response relationships.

The statistical treatment by Mr. Berry was exemplary. Various dose metrics were discussed, including duration of exposure, cumulative dose, cumulative dose in the first 9 years, and a time-weighted metric. A confidence interval was provided for the slope of the relative risk relationship with f/cc-yrs.

The Finkelstein study was adequate statistically, but the limited amount of data precluded subdivision of subjects beyond broad groupings. Even then, the numbers of deaths were very small and thus the associated risk estimates were imprecise. This imprecision would have been more obvious if the author had provided confidence intervals for the risk estimates.

*Exposure Gradient (2 points)* — Since these studies were selected from other cohort studies of asbestos workers because they provided good quality environmental data, it is not surprising that each had a detailed study of dose-response. The Quebec, Rochdale, Manville, and Charleston studies all showed strong gradients of risk with exposure both in terms of years of exposure and cumulative dust. Mr. Berry studied the nature of the relationship of lung cancer to cumulative exposure extensively. Because of relatively low average exposure in the cohort (only 5% of subjects had 100 f/cc-yrs or more), the overall excess mortality due to this cause with 100 f/cc-yrs of exposure did not reach conventional statistical significance.

Dr. Finkelstein's data suggest a linearly increasing mortality rate from mesothelioma with f/cc-yrs, but the relationship with lung cancer is much less clear. Both analyses were based upon small numbers so that the estimates of risk at defined exposure levels were less precise than those of the other two studies considered here.

*Discussion of Bias (1 point)* — All studies included discussion as to the possible biases inherent in their methodologic approach.

### A.3 Summary of Methodologic Quality

From the bottom line in Table 4 it can be seen that all six studies score quite highly and would be judged by most scientists as "good" epidemiology, especially in the context of occupational health. Dr. Enterline's study would appear to be the weakest primarily because of a questionable sampling strategy and relatively poor exposure data. Dr. J.C. McDonald's study in Quebec is rated slightly above the remaining four, but all five are quite comparable in methodologic quality.

## B. Comparison of Mortality Experience from the Six Studies with Environmental Data

The key results from the six studies are contained in Table 6. For all exposed subjects, the Berry study observed a relative risk for dust from lung cancer of 1.03 compared to 1.25 from the J.C. McDonald study, 2.7 from the Enterline study, 4.04 from the Dement study, and 5.12 from the Finkelstein study. The Peto study of the Rochdale experience has been puzzling because the relative risk for lung cancer in workers hired prior to 1951 was only 1.59 compared to 4.94 in workers hired after 1951. However, recent follow-up has shown a lower risk in the post-1951 cohort than was previously reported.<sup>19</sup>

Gastrointestinal cancer risks were mildly elevated in the studies by Drs. J.C. McDonald, Enterline, and Dement. The results from the Berry study indicated a negative relative risk for gastrointestinal cancer. However, in the Finkelstein study the relative risk from gastrointestinal cancer was significant, with a relative risk of 2.85.

The range of mesothelioma mortality levels was considerable. Dr. Enterline found only 5 cases of mesothelioma but suggested that many more cases occurred in the plant studied in men less than 65 and thus not eligible for the study. Dr. Dement included a systematic search for mesothelioma but found only one case. Ten deaths from mesothelioma were found in Quebec, 8 at Derbyshire (Ferodo), 8 at Scarborough (15 best evidence), and 8 at Rochdale.

Finally, one must be concerned about the competing risk of death from asbestosis or, more generally, non-specific fibrotic lung disease. Of the studies which reported these rates, all record substantial numbers of deaths from this cause which may have masked additional cancer cases. In each study, with the exception of Finkelstein, the number of deaths from pulmonary fibrosis was approximately equal to the number of excess deaths from lung cancer, so that, in the past at least, this has been an equally important end point. Mortality from lung cancer was almost twice the mortality from non-malignant respiratory disease in the Finkelstein cohort. From the Rochdale study, it would seem that the more recent risk of asbestosis is diminishing whereas lung cancer risk remains high. Mr. Peto warns this may be the effect of limited latency in a group hired since 1951. Furthermore, as noted above, more recent analysis has shown a lower lung cancer risk in the post-1951 follow-up.

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<sup>19</sup>E. Donald Acheson and Martin J. Gardner, *Asbestos: The Control Limit for Asbestos*, prepared for the U.K. Health and Safety Commission (London: Her Majesty's Stationery Office, 1983), paragraph 75, p. 12.

**Table 6**  
**Mortality Experience in Six Epidemiological Studies**

Result	J.C. McDonald*			Enterline			Peto			Dement			Berry*,**			Finkelstein***		
	O	E	RR§	O	E	RR	O	E	RR	O	E	RR	O	E	RR	O	E	RR
<b>a) Overall risks</b> (≥ 20 years since first exposure)																		
(i) Lung cancer	230	184.5	1.25	63	23.3	2.70	22	13.8	1.59 (Hired ≤ 1950)	23	5.7	4.04	143	139.5	1.03†	21	4.1	5.12
(ii) Gastrointestinal cancer	209	203	1.03	55	45.6	1.21	16	15.7	1.02 (Hired ≥ 1951)	9	7.10	1.27††	103	107.2	0.96	8	2.8	2.83
(iii) Pleural mesothelioma deaths	10			5			7			0			8			8	(15 best evidence)	
(iv) Peritoneal mesothelioma deaths	0			0			0			1			0			0		
(v) Fibrotic lung disease deaths	42			31			8	(Hired ≤ 1950)		15††			Not mentioned			9	(non-malignant respiratory disease)	
<b>b) Lung cancer by dust/fibre level</b>	mppcf-yrs	RR		mppcf-yrs	RR		Not reported			f/cc-yrs	RR	approx. mppcf-yrs	f/cc-yrs	RR		f/cc-yrs	RR	
< 10	< 10	1.0		< 125	1.98					< 27.4	2.23	< 9.1	50	1.03		< 30	2.31	
10-99	10-99	1.2		125-249	1.80					27.5-109.5	3.57	9.1- 36.5	100	1.06		30-75	6.15	
100-299	100-299	1.2		250-499	3.28					109.6-273	9.78	36.5- 91.3	150	1.09		75-105	12.08	
300-599	300-599	1.8		500-749	4.50					≥ 274	15.53	91.3-182.6				105-150	9.0	
≥ 600	≥ 600	2.9		≥ 750	7.78											≥ 150	2.69	

**Notes:** \* These data are for the men only, not the entire cohort.

The J.C. McDonald cohort included 10,939 men (3,291 dead), and the Berry cohort included 9,113 men (1,787 dead).

\*\* Ten years since first exposure.

\*\*\* Production workers only.

§ "O" means observed; "E" means expected; and "RR" means relative risk.

† Simulated exposure.

†† Includes all deaths from first exposure.

## C. Selikoff Study of Mortality Among Insulation Workers in the United States and Canada

As we mentioned at the outset of this chapter, Dr. Irving J. Selikoff's 1979 study of insulation workers in the United States and Canada did not contain any measurement of past exposure.<sup>20</sup> We feel that this deficiency is sufficiently grave to merit isolating the discussion of the Selikoff study from the six other studies which did include environmental data. The lack of accurate exposure data greatly detracts from the value of the study in providing proportionality constants for dose-response modelling. For this reason, we have refrained from undertaking a comprehensive evaluation of the study as we have done for the six other studies. Instead, we provide a brief review of the study.

The Selikoff insulation workers study documented the mortality experiences of 17,800 insulation workers who were enrolled in the International Association of Heat and Frost Insulators and Asbestos Workers in 1967. Dr. Selikoff and his colleagues observed 2,271 deaths between 1967 and 1976. The authors reported that prior to 1940, the subjects were exposed only to chrysotile asbestos and thereafter sustained exposure to both chrysotile and amosite asbestos during installation work.

The Selikoff study is characterized by comprehensive follow-up, robust data on death ascertainment, good information on smoking habits, and a particularly appropriate comparison population (white male age-specific U.S. death rates from the United States National Center for Health Statistics). Yet, these strengths are unable to compensate for the lack of environmental exposure data for the cohort.

Dr. Nicholson has attempted to provide exposure estimates which could be used as a proxy for the actual exposure experienced by the cohort.<sup>21</sup> The average estimate he arrived at for the cohort was based on recent measurements of asbestos exposure during insulation work. However, in order to account for both the reduced content of asbestos in the insulation products and the less frequent use of products containing asbestos during the period in which the measurement was taken, the average fibre intensity of 5 f/cc was multiplied by factors of 2 and 3 to generate estimates ranging from 10 to 15 f/cc. Only an average intensity can be used for the cohort, because there was not sufficient information available on the relative intensities of exposure each worker received. We assume an average exposure of 15 f/cc for the cohort.

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<sup>20</sup>Selikoff, Hammond, and Seidman, "Mortality Experience of Insulation Workers in the United States and Canada, 1943-1976."

<sup>21</sup>Nicholson, *Dose-Response Relationships for Asbestos and Inorganic Fibers*, p. 26.

The mortality experience of workers in the Selikoff study is presented in Table 7. The relative risk of lung cancer is 4.8 which is similar to the experience of the workers in the Finkelstein and Dement cohorts. Best evidence techniques reveal substantial mortality from mesothelioma: 170 deaths. In addition, the relative risk of other cancers is elevated to a factor of 1.5.

## **D. Derivation of Dose-Response Value from the Epidemiological Data**

Having discussed and evaluated the methodological approach and results contained in seven epidemiological studies, we now proceed to derive dose-response values for lung cancer and mesothelioma from these studies.

### **D.1 Lung Cancer**

We derive proportionality constants from each of the epidemiological studies discussed above by determining the ratio of the observed amount of lung cancer mortality to the cumulative exposure of the cohort. Ideally, the ratio or proportionality constant will be estimated by regressing the excess relative risk on cumulative dose, using a number of data points in a study. Each data point consists of the exposure and mortality rate for a subset of the cohort. However, where a satisfactory range of data points is not available, a single point representing the excess relative risk of mortality for the cohort and the corresponding average cumulative exposure will be used to produce the proportionality constant. This is considered a point estimate calculation. Since, by definition, the latter approach builds less information from the epidemiological study into the proportionality constant, the calculation is not as accurate as the former approach.

Once the proportionality constants have been derived, these values must be converted to a common dose metric to facilitate comparison. Since the generally accepted “active” component of the asbestos environment is a fibre (defined as having a length to width ratio of 3 to 1 or more, and a length of at least 5 microns) as opposed to non-fibrous dust, most standards are now specified in terms of fibres per cubic centimetre using optical microscopy and graticule counting techniques. (See Chapter 5.) The problem is thus to convert the particle counts from midget impingers used in earlier times to the equivalent fibre counts.

Unfortunately, all available side-by-side studies of the two methods suggest wide variability in conversion factors from plant to plant and job to job. In fact, it is not even clear that repeat observations over time in the same location provide a reliable conversion factor. The data available are

Table 7  
 Relative Risk of Excess Mortality from Asbestos-Related Disease  
 in Insulation Workers Cohort

	Observed*		Expected	Relative Risk (Best Evidence)
	Death Certificate	Best Evidence		
Lung cancer	397	450	93.7	4.8
Gastrointestinal cancer	89	93	53.2	1.8
Pleural mesothelioma	—	61	—	—
Peritoneal mesothelioma	—	109	—	—
Other cancers	258	199	130.2	1.5
Fibrotic lung disease	177	204	53.8	3.8

**Note:** \*Overall observed risk, 20 or more years after first exposure.

**SOURCE:** Adapted from: Irving J. Selikoff, E. Cuyler Hammond, and Herbert Seidman, "Mortality Experience of Insulation Workers in the United States and Canada, 1943-1976," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 108 (Table 16).

quite limited. As discussed earlier, Dr. Dement has incorporated a conversion factor of 3 f/cc equals 1 mppcf for most of his occupations based on U.S. public health survey data. These data were published separately by Ayer, Lynch, and Fanney in 1965 as part of a survey of four asbestos factories in the United States.<sup>22</sup> The overall mean conversion factor for the four plants was 9.5 f/cc per 1 mppcf, but it appears that the plant which Dr. Dement studied was lower at 5.2. This is quite close to Dr. Dement's conversion factor of 8 for fibre preparation and 3 for the remainder of the plant. Ayer, Lynch, and Fanney's average conversion is probably the best value we have available to convert the Enterline data into f/cc-yrs.

Dr. Graham W. Gibbs and Dr. Maurice Lachance presented, in their 1974 paper analyzing the Quebec mines and mills, side-by-side measurements of particles and fibres.<sup>23</sup> The data showed very little correlation and certainly wide variability in conversion ratios from location to location. In Quebec, a document prepared for the Comité d'étude sur la salubrité dans l'industrie de l'amiante, on reviewing all available data, recommended conversions of between 3 and 7 depending on location.<sup>24</sup> This range will be used to convert Quebec data.

The "raw" risk estimates in terms of exposure units of the original study reports are given in the bottom of Table 6. In four of the five studies which reported lung cancer mortality as a function of cumulative exposure, relative risk increases reasonably smoothly with exposure. However, for the Finkelstein study, the relationship is much less clear and the resulting linear model provides a poor fit to those data. This is probably due primarily to small numbers of subjects in each exposure group.

From these data, proportionality constants are calculated using regression techniques as discussed above. Of course, the uncertainty surrounding the proportionality constant derived from the Finkelstein data will be large considering the difficulty in fitting a straight line to the disparate response observations in that study.

For the Peto and Selikoff data, proportionality constants are calculated by using a point estimate rather than deriving the slope of the best fit

<sup>22</sup>Howard E. Ayer, Jeremiah R. Lynch, and Julius H. Fanney, "A Comparison of Impinger and Membrane Filter Techniques for Evaluating Air Samples in Asbestos Plants," *Annals of the New York Academy of Sciences* 132, Art. 1 (31 December 1965): 274-287.

<sup>23</sup>Graham W. Gibbs and Maurice Lachance, "Dust Exposure in the Chrysotile Mines and Mills of Quebec," *Archives of Environmental Health* 24 (March 1972): 189-197.

<sup>24</sup>See Michel Dagbert, *Études de corrélation de mesures d'empoussièrement dans l'industrie de l'amiante*, Document 5 for Québec, Comité d'étude sur la salubrité dans l'industrie de l'amiante (Beaudry Report), René Beaudry, J.C.P., Président (Montréal, Québec: l'éditeur officiel du Québec, October 1976). See also, J. Corbett McDonald and F. Douglas K. Liddell, "Mortality in Canadian Miners and Millers Exposed to Chrysotile," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 8.

line through a range of observations. For the Peto study, proportionality constants were calculated separately for the pre- and post-1951 cohorts and then compared. This exercise produced values of 0.002 and 0.013 for the pre- and post-1951 cohorts respectively. We have adopted a constant of 0.01 for the combined data, on the grounds that this value falls between the values for the two cohorts, assuming that both groups had roughly equivalent exposures of 300 f/cc-yrs. Recent follow-up shows a reduced risk in the post-1951 cohort, lowering the range within which the appropriate coefficient may lie. The appropriate constant may therefore be closer to 0.005 than to 0.01. On the other hand, it has also been suggested that the dust levels at Rochdale may have been overestimated, thus leading to underestimates of the dose-response relationship.<sup>25</sup> This would cancel out the overestimate of the post-1951 disease. We, therefore, use the coefficient of 0.01, recognizing that considerable uncertainty attaches to this value, as to many of the others derived here.

For the Selikoff cohort, a single point estimate is used. The relative risk of lung cancer reported in Table 7 is 4.8 for workers with more than 20 years of follow-up. Converting to an excess risk, and dividing by 375 f/cc-yrs of exposure, yields a lung cancer coefficient of 0.0101. The exposure of 375 f/cc-yrs is based on an average exposure of 15 f/cc for 25 years.

The resulting lung cancer coefficients for all seven studies are presented in the top half of Table 8. The bottom half of Table 8 presents the estimated risk of lung cancer deaths at various levels of exposure based upon a linear model of excess risk. Note the range of values that is produced: the slopes derived from the studies by J.C. McDonald, Enterline, and Berry are roughly comparable at 0.000463 (at 3 f/cc conversion), 0.000693, and 0.00058 respectively. The Dement and Finkelstein slopes are highest at 0.0416 and 0.042 respectively. The almost identical values derived from point estimates in the Peto and Selikoff studies, 0.01, fall between the Dement and Finkelstein values, on the one hand, and the J.C. McDonald, Enterline, and Berry values, on the other.

Comparison of the risk of lung cancer at a cumulative exposure of 25 f/cc-yrs indicates that those studies which generated slopes with a low value not surprisingly predict only a slight increase in the relative risk of lung cancer, while the values derived from both the Dement and Finkelstein studies predict a doubling of the relative risk at 25 f/cc-yrs.

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<sup>25</sup>Acheson and Gardner, *Asbestos: The Control Limit for Asbestos*, paragraph 96, p. 15. See also, W.J. Smither and H.C. Lewinsohn, "Asbestosis in Textile Manufacturing," in *Biological Effects of Asbestos*, eds. P. Bogovski et al., IARC Scientific Publications, no. 8 (Lyon, France: International Agency for Research on Cancer, 1973), pp. 169-174.

Table 8  
Estimated Relative Risk Coefficients for Lung Cancer

	J.C. McDonald	Enterline	Peto	Dement	Berry	Finkelstein	Selkoff
Coefficient	at 3 f/cc	at 9.5 f/cc		at 3 and 8 f/cc			
Value C*	0.000463	0.000693	0.01	0.0416	0.00058	0.042	0.0101
	at 7 f/cc						
	0.000198						
Estimated Risk	3 f/cc	7 f/cc					
25 f/cc-yrs	1.012	1.005	1.25	2.04	1.015	2.05	1.25
50 f/cc-yrs	1.023	1.010	1.5	3.08	1.029	3.1	1.50
75 f/cc-yrs	1.035	1.015	1.75	4.12	1.044	4.15	1.76
100 f/cc-yrs	1.046	1.020	2.0	5.16	1.058	5.2	2.01

**Note:** \*The coefficient "C" may be inserted in the equation  $RR = 1 + C \times FCC \times D$  to estimate the relative risk of lung cancer from exposure to an asbestos concentration of FCC for a duration of D years.

## D.2 Derivations for Mesothelioma Dose-Response Functions

Data on mesothelioma mortality from three of the studies discussed above are used to produce three estimated mesothelioma dose-response functions. Even though all seven epidemiological studies report some level of mesothelioma mortality, we are unable to calculate proportionality constants for all of them because not all studies present adequate mesothelioma mortality data. The three mesothelioma constants are all obtained from using regression analysis to fit the equation  $MI(a) = K \cdot FCC \cdot D \cdot [T^4 - (T-D)^4]$  to the data shown in Table 9. We discuss below the derivation of the data used as inputs to the regression analysis for the Peto, Finkelstein, and Selikoff cohorts.

*Peto's Rochdale Study* — We combine the mesothelioma mortality of the pre- and post-1951 cohorts with the corresponding person-years of observation, in 5-year groups, to produce the data in Table 9. We assume that these workers experienced an average exposure of 30 f/cc for an average of 10 years.

*Finkelstein's Scarborough Study* — The mortality rates of each 5-year follow-up group are taken directly from the Finkelstein study. Data supplied to us by Dr. Finkelstein allow the determination that these workers were exposed, on average, to 5.25 f/cc for 10.5 years.

*Selikoff's Insulators Study* — The mortality rates of each 5-year follow-up group are taken directly from the Selikoff study. We have assumed, based on that study and other sources, that these workers were exposed to an average of 15 f/cc for 25 years.

## Section 3:

### Simulation of Predicted Disease

#### A. Introduction

With the values that have been derived for the lung cancer and mesothelioma dose-response functions, we can now simulate the effect of different exposure intensities on the level of mortality that will be experienced by a hypothetical workforce using the various constants from the seven studies analyzed above.

We assume that this workforce consists of 1,000 workers who are all exposed to the same level of asbestos. We also assume that 23% of the above workforce is female and 77% is male. In addition, we assume that

Table 9  
Derivation of Mesothelioma Constants

	Peto* (Rochdale)	Finkelstein** (Scarborough)	Selikoff*** (Insulators)
<b>Assumed Exposure</b>			
Intensity (f/cc)	30	5.25	15
Duration (yrs)	10	10.5	25
<b>Mesothelioma Mortality Rate (per thousand exposed workers)</b>			
<b>Time Since First Exposure</b>			
10-14	0	0.4	0
15-19	0	0.4	0.15
20-24	0.43	2.7	0.29
25-29	1.26	6.3	1.55
30-34	2.39	9.6	2.76
35-39	3.94		6.29
40-44			6.33
45+			8.1
<b>Derived Constant K</b>	$7.2 \times 10^{-11}$	$213 \times 10^{-11}$	$13.3 \times 10^{-11}$

- SOURCES: \* Julian Peto, "Lung Cancer Mortality in Relation to Measured Dust Levels in an Asbestos Textile Factory," in *Biological Effects of Mineral Fibres*, vol. 2, ed. J.C. Wagner, IARC Scientific Publications, no. 30 (Lyon, France: International Agency for Research on Cancer, 1980), Table 1, p. 830.
- \*\* Murray M. Finkelstein, "Mortality Among Employees of an Ontario Asbestos-Cement Factory," Toronto, Ontario Ministry of Labour, February 1983, revised September 1983, Table 2. (Mimeographed.)
- \*\*\* Irving J. Selikoff, E. Cuyler Hammond, and Herbert Seidman, "Mortality Experience of Insulation Workers in the United States and Canada, 1943-1976," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 109 (Table 17).

50% of the workers in the exposed population are smokers while the other 50% are not. Given that the average employment duration in three Ontario brake plants was found to vary between 3.8 years at one plant and 12.3 years at another, we have based most of our projections on an average employment duration of 10 years.<sup>26</sup> However, because exposure durations exceeding 25 years have been reported (e.g., at the Scarborough plant), we have used a duration of 25 years to represent long-term exposure. Lastly, the age at which work-related asbestos exposure began for the workforce is assumed to be 22. These assumptions concerning population characteristics will be maintained throughout the analysis unless otherwise indicated.

Our primary analysis will simulate the effects of reducing asbestos exposure levels. Several other analyses will also be performed. First, we will simulate the disease incidence in a workforce consisting only of non-smokers to contrast with our base workforce of 50% smokers. The interest in this analysis turns on the high risk of lung cancer sustained by asbestos workers who smoke and our model's ability to differentiate between the impact of asbestos on smokers and non-smokers. Second, we will examine the effects of varying the age of first exposure. This analysis is suggested by the impact of excess relative risk that rises slowly with age in both the lung cancer and mesothelioma dose-response function. Finally, we will simulate the effect of different rates of turnover in the workforce on the aggregate mortality of the workforce. Turnover will not affect lung cancer mortality but will affect mortality from mesothelioma, when the recruitment of new workers is among the young.

## B. Changing Fibre Levels

In Table 10 we report the predicted asbestos-related mortality experienced by our hypothetical workforce at different fibre levels. The duration of exposure for this population is 10 years, and the age at first exposure is 22.

Noteworthy is the range of mortality evident at any given exposure level; for example, at 2 f/cc from 0.3 deaths and 3.9 life-years lost based on the J.C. McDonald study (at 7 f/cc conversion) to 295.4 deaths and 4,193.0 life-years lost from the values obtained from the Finkelstein study. These numbers differ by a factor of almost 1,000. Between these two extremes lies

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<sup>26</sup>Sally Luce and Gene Swimmer, *Worker Attitudes About Health and Safety in Three Asbestos Brake Manufacturing Plants*, Royal Commission on Asbestos Study Series, no. 6 (Toronto: Royal Commission on Asbestos, 1982), p. 4.2. A recent study of three U.S. asbestos manufacturing plants reported that the average tenure of workers was 8.7 years, 7.6 years, and 9.2 years. See Alison D. McDonald et al., "Dust Exposure and Mortality in an American Chrysotile Asbestos Friction Products Plant," *British Journal of Industrial Medicine*, in press, 1984, p. 6.

the mortality predicted by the Dement, Selikoff, and Peto studies with 62, 32.5, and 24.6 deaths predicted respectively at 2 f/cc. When the exposure is reduced by a factor of 10 to 0.2 f/cc, the mortality predicted by four of the eight studies is still in excess of 1 death per 1,000: Finkelstein (33.6); Dement (6.5); Selikoff (3.3); and Peto (2.5).

Table 11 presents estimates similar to those calculated for Table 1, but based on a duration of 25 years rather than 10 years. The relative levels of mortality risk are similar to those in Table 2. The predictions based on the Finkelstein study are highest, at a risk of 459.5 deaths for 2 f/cc, compared to the risk based on the J.C. McDonald study of 0.8 deaths.

By comparing the figures for a particular fibre level and a given study in Table 11 with the corresponding data in Table 10, the effect of increasing the duration of exposure can be observed. In the predictions in which only lung cancer mortality is calculated from the original study, the difference in mortality levels between the two tables reflects the linear impact of incremental duration on risk. For instance, at 1 f/cc the risk of mortality predicted by the Enterline study at 10 and 25 years is 0.54 and 1.35 respectively. This represents an increase in risk of death of 150% in response to an increase in duration of 150%. This is not merely coincidental; the 150% increase in duration causes a 150% increase in cumulative exposure, which causes a 150% increase in excess relative risk which acts on the background lung cancer rate. Thus, for these studies proportional increases in duration induce an exactly proportional increase in mortality. However, this relationship is somewhat less than proportional for the predictions based on the Finkelstein and Dement studies. This is because the lung cancer dose-response function is more powerful for these studies and causes a greater increase in the amount of asbestos-related mortality. As both the fibre level and the duration increase, the removal of workers suffering an asbestos-related death also increases, leaving fewer workers to face the mortality rate as the population ages. Therefore, when duration increases by 150% in the Dement study, mortality at 2 f/cc increases by only 132%.

In those predictions in which both lung cancer and mesothelioma mortality are calculated, an increase in duration is always matched by a less than proportional increase in mortality. This is attributable partly to the "removal effects" discussed above and partly to the behaviour of the mesothelioma dose-response function. We will defer a discussion of this latter point until the worker turnover analysis is presented.

### C. The Effect of Exposing Non-Smokers Only

In Table 12 we present side-by-side calculations of the mortality that will occur in a workforce which is divided equally between smokers and non-smokers and a workforce containing non-smokers only. These calcula-

Table 10  
Predicted Lifetime Mortality Risk for 1,000 Asbestos Workers Exposed to Different Fibre Levels for 10 Years\*

Epidemiological Study	Fibre Level	Lung Cancer Mortality	Mesothelioma Mortality	Total Mortality	Total Life-Years Lost
<b>Berry</b> [Derbyshire (Ferodo), Friction Materials]	2 1 0.5 0.2	0.9 0.5 0.2 0.1	— — — —	0.9 0.5 0.2 0.1	11.3 5.6 2.8 1.1
<b>Dement</b> (Charleston, Textiles)	2 1 0.5 0.2	62.0 31.8 16.1 6.5	— — — —	62.0 31.8 16.1 6.5	782.1 397.7 200.5 80.6
<b>Enterline</b> (Manville, Retirees)	2 1 0.5 0.2	1.1 0.54 0.27 0.11	— — — —	1.1 0.54 0.27 0.11	13.5 6.7 3.4 1.4
<b>Finkelstein</b> (Scarborough, Asbestos- Cement Products)	2 1 0.5 0.2	56.8 30.5 15.8 6.5	238.6 128.1 66.4 27.1	295.4 158.6 82.2 33.6	4,193.0 2,208.1 1,133.4 460.6
<b>J.C. McDonald 1</b> (Quebec, Mining @ 3 f/cc)	2 1 0.5 0.2	0.7 0.4 0.2 0.1	— — — —	0.7 0.4 0.2 0.1	9.0 4.5 2.3 0.9
<b>J.C. McDonald 2</b> (Quebec, Mining @ 7 f/cc)	2 1 0.5 0.2	0.3 0.16 0.1 0.03	— — — —	0.3 0.16 0.1 0.03	3.9 1.9 1.0 0.4

Table 10 (continued)  
 Predicted Lifetime Mortality Risk for 1,000 Asbestos Workers Exposed to Different Fibre Levels for 10 Years\*

Epidemiological Study	Fibre Level	Lung Cancer Mortality	Mesothelioma Mortality	Total Mortality	Total Life-Years Lost
Peto (Rohdale, Textiles)	2	15.4	9.2	24.6	321.3
	1	7.8	4.6	12.4	161.4
	0.5	3.9	2.3	6.2	80.9
	0.2	1.6	0.9	2.5	32.4
Selikoff (U.S./Canada, Insulators)	2	15.5	17.0	32.5	431.3
	1	7.8	8.5	16.4	216.8
	0.5	3.9	4.3	8.2	108.7
	0.2	1.6	1.7	3.3	43.6

Notes: \* Age at first exposure = 22; 385 male smokers; 385 male non-smokers; 115 female smokers; 115 female non-smokers.

Table 11  
Predicted Lifetime Mortality Risk for 1,000 Asbestos Workers Exposed to Different Fibre Levels for 25 Years\*

Epidemiological Study	Fibre Level	Lung Cancer Mortality	Mesothelioma Mortality	Total Mortality	Total Life-Years Lost
<b>Berry</b> [Derbyshire (Ferodo), Friction Materials]	2	2.3	—	2.3	27.9
	1	1.1	—	1.1	14.0
	0.5	0.6	—	0.6	7.0
	0.2	0.2	—	0.2	2.8
<b>Dement</b> (Charleston, Textiles)	2	144.2	—	144.2	1,845.1
	1	76.4	—	76.4	961.2
	0.5	39.3	—	39.3	490.7
	0.2	16.0	—	16.0	198.8
<b>Enterline</b> (Manville, Retirees)	2	2.7	—	2.7	33.4
	1	1.35	—	1.35	16.7
	0.5	0.7	—	0.7	8.4
	0.2	0.27	—	0.27	3.3
<b>Finkelstein</b> (Scarborough, Asbestos- Cement Products)	2	127.1	332.3	459.5	6,410.7
	1	72.0	187.5	259.5	3,500.0
	0.5	38.4	99.7	138.0	1,830.5
	0.2	15.9	41.4	57.3	752.5
<b>J.C. McDonald 1</b> (Quebec, Mining @ 3 f/cc)	2	1.8	—	1.8	22.3
	1	0.9	—	0.9	11.2
	0.5	0.5	—	0.5	5.6
	0.2	0.2	—	0.2	2.2
<b>J.C. McDonald 2</b> (Quebec, Mining @ 7 f/cc)	2	0.8	—	0.8	9.5
	1	0.4	—	0.4	4.8
	0.5	0.2	—	0.2	2.4
	0.2	0.1	—	0.1	1.0

Table 11 (continued)  
 Predicted Lifetime Mortality Risk for 1,000 Asbestos Workers Exposed to Different Fibre Levels for 25 Years\*

Epidemiological Study	Fibre Level	Lung Cancer Mortality	Mesothelioma Mortality	Total Mortality	Total Life-Years Lost
<b>Peto</b> (Rochdale, Textiles)	2	37.7	14.0	51.7	658.4
	1	19.2	7.1	26.2	332.7
	0.5	9.7	3.6	13.2	167.2
	0.2	3.9	1.4	5.3	67.1
<b>Selikoff</b> (U.S./Canada, Insulators)	2	37.9	25.8	63.7	819.4
	1	19.3	13.1	32.4	414.5
	0.5	9.7	6.6	16.3	208.5
	0.2	3.9	2.6	6.6	83.7

Notes: \* Age at first exposure = 22; 385 male smokers; 385 male non-smokers; 115 female smokers; 115 female non-smokers.

tions are based on an exposure intensity of 1 f/cc and a duration of 10 years. The level of lung cancer mortality is reduced by more than 75% in the non-smoking workforce based on all of the studies. Perversely, the level of mortality for mesothelioma actually increases in the non-smoking workforce.

This rather curious phenomenon occurs because eliminating smoking will not only lower the background levels of lung cancer, but will improve the likelihood of survival of the population. This is because non-smokers are generally healthier than smokers and live longer. Although the mesothelioma death rate is completely independent of smoking habits, the survival probabilities to which it is applied are not. Since increasing the proportion of non-smokers in the workforce will improve the survival prospects of the population, a higher proportion of the exposed population will live to an age when the risk of developing mesothelioma is greatest.

Noteworthy also in Table 12 is the relatively constant percentage change in the amount of mortality savings accruing from employing non-smokers only among those projections based on lung cancer mortality only. For the Berry, Dement, Enterline, and J.C. McDonald studies, mortality is reduced by 70 to 80% when mortality is calculated only for non-smokers. The mortality savings for the Peto and Selikoff projections are lower at 44% and 30% respectively because these projections include a substantial risk of mesothelioma. The mortality decrease for the projections based on the Finkelstein study is only 4% because of the very high mesothelioma risk in that study.

Finally, by examining the mortality projections for non-smokers based on those studies generating both lung cancer and mesothelioma dose-response functions, the importance of mesothelioma as the cause of death among non-smokers can be seen; death from mesothelioma is from 3 to 21 times more prevalent among non-smokers exposed to asbestos than is mortality from lung cancer in this cohort.

## **D. The Effect of Varying the Age of First Exposure**

Table 13 demonstrates the reduction of mortality realized from the employment of older workers. For the projections based on the Finkelstein study, the decrease in asbestos-related mortality occasioned by increasing the age of the exposed population amounts to almost 78% of the mortality experienced by a population first exposed at age 22. However, the projections based on the Enterline study indicate only a 7.4% reduction in mortality for increasing the age of first exposure.

Table 12

The Predicted Effects of Smoking on Mortality Rates\*

Epidemiological Study	50% Smokers and 50% Non-Smokers			100% Non-Smokers			Difference	
	Lung Cancer Mortality	Mesothelioma Mortality	Combined Mortality	Lung Cancer Mortality	Mesothelioma Mortality	Combined Mortality	Lung Cancer Mortality	Mesothelioma Mortality
<b>Berry</b> (Derbyshire (Ferodo), Friction Materials)	0.5	—	0.5	0.104	—	0.104	- 0.396	—
<b>Dement</b> (Charleston, Textiles)	31.8	—	31.8	7.3	—	7.3	-24.5	—
<b>Enterline</b> (Manville, Retirees)	0.54	—	0.54	0.12	—	0.12	- 0.42	—
<b>Finkelstein</b> (Scarborough, Asbestos-Cement Products)	30.5	128.1	158.6	7.0	145.9	152.9	-23.6	+17.8
<b>J.C. McDonald 1</b> (Quebec, Mining @ 3 f/cc)	0.4	—	0.4	0.08	—	0.08	- 0.32	—
<b>J.C. McDonald 2</b> (Quebec, Mining @ 7 f/cc)	0.16	—	0.16	0.04	—	0.04	- 0.12	—
<b>Peto</b> (Rochdale, Textiles)	7.8	4.6	12.4	1.8	5.3	7.0	- 6.0	+ 0.7
<b>Selikoff</b> (U.S./Canada, Insulators)	7.8	8.5	16.4	1.8	9.7	11.5	- 6.0	+ 1.2

Notes: \* Duration = 10; Fibre intensity = 1 f/cc; Age at first exposure = 22; Males = 770; Females = 230.

**Table 13**  
**The Predicted Effect of Increasing the Age at**  
**which the Workforce is First Exposed to Asbestos\***

<b>Epidemiological Study</b>	<b>Mortality Age = 22</b>	<b>Mortality Age = 52</b>	<b>Mortality Difference</b>
<b>Berry</b> (Derbyshire (Ferodo), Friction Materials)	0.5	0.4	0.1
<b>Dement</b> (Charleston, Textiles)	31.8	29.0	2.8
<b>Enterline</b> (Manville, Retirees)	0.54	0.5	0.04
<b>Finkelstein</b> (Scarborough, Asbestos-Cement Products)	158.6	35.4	123.2
<b>J.C. McDonald 1</b> (Quebec, Mining @ 3 f/cc)	0.4	0.33	0.07
<b>J.C. McDonald 2</b> (Quebec, Mining @ 7 f/cc)	0.16	0.14	0.02
<b>Peto</b> (Rochdale, Textiles)	12.4	7.3	5.1
<b>Selikoff</b> (U.S./Canada, Insulators)	16.4	7.5	8.8

**Notes:** \*Fibre intensity = 1 f/cc; Duration = 10 Years; 385 male non-smokers; 385 male smokers; 115 female non-smokers; 115 female smokers.

Again, the difference between the percentages is accounted for by the inclusion of mesothelioma mortality in the Finkelstein study. Since the amount of mesothelioma mortality is relatively low for the first two decades after exposure, increasing the age at first exposure of workers employed in the asbestos industry reduces the likelihood of surviving to an age where the risk of developing mesothelioma is greatest.

On the other hand, if the only mortality risk is from lung cancer, increasing the age of first exposure does not achieve any significant mortality reduction. To elaborate, increasing the age of the workforce reduces lung cancer mortality very little because lung cancer mortality is dependent upon the age-specific lung cancer rates for the general population. At age 62 (10 years after first exposure to account for the lag period), the rate of lung cancer mortality in the general population is substantially greater than the rate at age 32. Thus, increasing the age of the workforce increases the number of workers who are alive to suffer elevated levels of lung cancer risk.

With a different set of assumptions, the effect of this change could even become negative. We incorporate a 10-year lung cancer lag period in our calculations because we feel it is improbable that workers would experience an increase in the risk-gradient for asbestos-related lung cancer immediately upon exposure. However, if we allowed our workforce immediately to suffer increased levels of lung cancer upon exposure, the level of mortality from lung cancer could increase.

Finally, we examine the effect on mortality risks of reducing the age at first exposure in connection with exposure to very low levels of airborne asbestos fibre concentrations, to explore the risks to which building occupants might be exposed. Since building insulation is the substance to which much of the Selikoff cohort was exposed, we use the model derived from the Selikoff data as the basis for this simulation. An exposure of 0.001 f/cc is assumed, based on Chapter 9 of this Report. The lifetime risk of contracting a fatal disease from 10 years of exposure to 0.001 f/cc beginning at age 22 is 0.00002. The risk to a school child may be derived using the same model, but a younger age at first exposure. If the person is first exposed at age 7, and the exposure continues for 10 years, the lifetime risk of contracting a fatal asbestos-related disease is 0.000032, or almost double that of a 22 year old adult. Thus, according to these models, a child of 7 faces a risk of asbestos-related mortality from a given exposure in a building about twice that faced by an adult of age 22.

## **E. The Effect of Decreasing the Frequency of Worker Turnover**

Consider the mortality that might result from exposing workers in 1,000 jobs for 20 years to 1 f/cc, under differing rates of labour turnover, with each worker experiencing his first exposure at age 22. If the same workers remain for only 4 years, there would be five cohorts with exposure durations of 4 years each. The predicted mortality for each cohort is shown in Column 1 of Table 14, and the total for the five cohorts is shown in Column 2. If workers remain for 10 years, there would be 2 cohorts with exposure durations of 10 years each. The mortality for each cohort is shown in Column 3 of Table 14, with the total for the two cohorts shown in Column 4. If the same workers remain for 20 years, there is one cohort with 20 years' exposure. The predicted mortality for this cohort is shown in Column 5 of Table 14.

As mentioned previously, if asbestos exposure caused only lung cancer, worker turnover would have little impact on the aggregate risk faced by the exposed population. However, when mortality from mesothelioma is calculated, differing lengths of duration will influence the levels of mortality that result. A comparison of Columns 2, 4, and 5 in Table 14 supports these propositions. The projections based on the Berry, Dement, Enterline, and J.C. McDonald studies, which include lung cancer only, show a negligible difference in mortality between five workforces exposed for 4 years and one workforce exposed for 20 years. Yet, the other projections, based on both mesothelioma and lung cancer mortality, show a significant difference between the amount of asbestos-related mortality predicted at different exposure durations. For example, mortality is reduced by 40% based on the Finkelstein study, 20% based on the Peto study, and 24% based on the Selikoff study as a result of reducing the number of workforces employed during 20 years from five to one.

Table 14  
The Predicted Effect of Decreasing the Frequency of Worker Turnover

Epidemiological Study	1 Duration = 4	2 Mortality for 20 Years	3 Duration = 10	4 Mortality for 20 Years	5 Duration = 20
<b>Berry</b> [Derbyshire (Ferodo), Friction Materials]	0.18	0.9	0.5	0.9	0.91
<b>Dement</b> (Charleston, Textiles)	12.9	64.5	31.8	63.6	62.0
<b>Enterline</b> (Manville, Retirees)	0.22	1.1	0.54	1.1	1.1
<b>Finkelstein</b> (Scarborough, Asbestos- Cement Products)	78.1	390.3	158.6	317.3	235.9
<b>J.C. McDonald 1</b> (Quebec, Mining @ 3 f/cc)	0.15	0.75	0.4	0.75	0.72
<b>J.C. McDonald 2</b> (Quebec, Mining @ 7 f/cc)	0.07	0.35	0.16	0.32	0.3
<b>Peto</b> (Rochdale, Textiles)	5.4	27.0	12.4	24.8	22.0
<b>Selikoff</b> (U.S./Canada, Insulators)	7.4	36.8	16.4	32.7	27.8

**Notes:** \*Fibre intensity = 1 f/cc; Age at first exposure = 22; 385 male non-smokers; 385 male smokers; 115 female non-smokers; 115 female smokers.



## Chapter 8    Beyond Control Limits: Protecting Health in Fixed Place Industry

### A. Introduction

Fundamental to our recommendation of control limits in Chapter 7 is the recognition that the Regulation Respecting Asbestos requires that “Every employer shall take all necessary measures and procedures by means of engineering controls, work practices and hygiene practices and facilities to ensure that the time-weighted average exposure of a worker to airborne asbestos is reduced to *the lowest practical level . . .*”<sup>1</sup> (Emphasis added.) The Regulation goes on to specify a control level, but the “lowest practical level” is just as much a part of the Regulation as are the numerical control limits. While we have endorsed control limits for some exposure to asbestos, we recognize that compliance with these control limits does not eliminate all health risks to asbestos workers. We therefore attach major importance to reducing worker exposures to levels below the control limit, as required by the above-quoted language from section 4(1) of the Regulation Respecting Asbestos. This language enshrines in Ontario what we take to be a version of what is commonly referred to as the ALARA principle (As Low As Reasonably Achievable). A specific focus of this chapter will be on means of adhering to this principle. More generally, we are concerned with the enforcement and other aspects of the occupational health and safety system that have a bearing on the protection of worker health.

We perceive that problems of industrial health are particularly complex when compared to problems of industrial safety. In most cases, the

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<sup>1</sup> Regulation Respecting Asbestos, O. Reg. 570/82, s. 4(1), made under the *Occupational Health and Safety Act*, R.S.O. 1980, c. 321.

dangers leading to industrial accidents are evident and the consequences immediate. Avoidance of the danger is frequently understandable and controllable at the shop floor level. Industrial disease, on the other hand, is primarily related to the environment in the workplace, which may be influenced by work practices but is largely beyond the control of the worker.<sup>2</sup> The worker may be unaware of, or at best only vaguely aware of, the existence of a hazard. The hazard may not be detectable by human senses; the consequences may not be evident for 10 or 20 years, or even until the next generation, and may strike randomly. For these reasons, occupational health is even more challenging than occupational safety in a setting where both place enormous requirements upon the many individuals and organizations involved and where complaints, particularly from labour unions and workers, have been numerous and pointed.

The *Occupational Health and Safety Act*<sup>3</sup> and its accompanying Regulation Respecting Asbestos establish and posit the existence of an Internal Responsibility System [hereafter IRS]. This system, through a variety of mechanisms, internalizes responsibility for workplace health to those most directly involved in the workplace: the employer, supervisor, and worker. While the IRS operates within the workplace, the Ministry of Labour provides both support for the IRS and its own enforcement functions under the Act through the activities of its Occupational Health and Safety Division.

In this chapter, we shall: (i) describe Ontario's occupational health and safety legislation with its focus on the IRS; (ii) sketch the role of the Ministry of Labour and its relation to the IRS; (iii) identify certain problems in the IRS and recommend some measures designed to deal with these problems; and (iv) assess the importance, in the particularly challenging realm of occupational health, of changes beyond the IRS that will help ensure the protection of workers.

## **B. The Ontario Setting: The Centrality of the Internal Responsibility System**

On October 1, 1979, the *Occupational Health and Safety Act* was proclaimed in Ontario. This was a vital step in the evolution of workplace health and safety legislation, which began in the province in 1884 with *The Ontario Factories Act*.<sup>4</sup> At the time that the new legislation was passed, it replaced five acts operating in this field and administered by three govern-

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<sup>2</sup>Ontario, *Report of the Royal Commission on the Health and Safety of Workers in Mines* (Ham Report), James M. Ham, Commissioner (Toronto: Ministry of the Attorney General, 1976), p. 16.

<sup>3</sup>*Occupational Health and Safety Act*, R.S.O. 1980, c. 321.

<sup>4</sup>*The Ontario Factories Act*, 1884, 47 Vict., c. 39.

ment ministries. The *Occupational Health and Safety Act* consolidated all previous legislation.<sup>5</sup>

An important catalyst in the creation of the new Act was the *Report of the Royal Commission on the Health and Safety of Workers in Mines* (the Ham Report).<sup>6</sup> A central theme of this document was that the system of internal responsibility should infuse the relationships among all participants in the workplace.<sup>7</sup> The main elements of the IRS would include an enhanced role for workers in dealing with workplace health and safety issues and a more continuous and accountable structure for problem-solving in this area. The major instrument for realizing these goals would be the joint health and safety committee. These principles became a cornerstone of the *Occupational Health and Safety Act* and the foundation for the regulations made thereunder. The Act created a new framework for organizing the various parties and responsibilities involved in protecting workers from both industrial accident and disease. Let us describe the elements of this Act and of the Regulation Respecting Asbestos which are central to this framework.

Section 41(1) of the Act gives the Cabinet authority to “. . . make such regulations as are advisable for the health or safety of persons in or about a work place.” Section 41(2) of the Act goes on to enumerate possible regulatory areas, including the following:

11. respecting the reporting by physicians and others of workers affected by any biological, chemical or physical agents or combination thereof;
12. regulating or prohibiting atmospheric conditions to which any worker may be exposed in a work place;
13. prescribing methods, standards or procedures for determining the amount, concentration or level of any atmospheric condition or any biological, chemical or physical agent or combination thereof in a work place;
14. prescribing any biological, chemical or physical agent or combination thereof as a designated substance;
15. prohibiting, regulating, restricting, limiting or controlling the handling of, exposure to, or the use and disposal of any designated substance.

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<sup>5</sup>Ontario, Ministry of Labour, Written submission to the Royal Commission on Asbestos, #43, February 1981, pp. 10–25.

<sup>6</sup>Ontario, *Report of the Royal Commission on the Health and Safety of Workers in Mines*.

<sup>7</sup>*Ibid.*, p. 6.

The Act defines a "designated substance" as "... a biological, chemical or physical agent or combination thereof prescribed as a designated substance to which the exposure of a worker is prohibited, regulated, restricted, limited or controlled."<sup>8</sup> To date, the Government of Ontario has designated six substances. It is in the process of designating six more and has given notice of four more to be designated.<sup>9</sup> Thus, the action of designating a substance triggers the regulation-making process,<sup>10</sup> with its attendant numerical control limits and codes for respiratory equipment, measurement, and medical surveillance.

The regulations reflect the Internal Responsibility System by delineating the powers and responsibilities of parties in the workplace to ensure the identification and control of designated substances. Furthermore, the Ministry of Labour has built its enforcement activities around the IRS. The routine, accident investigation, and compliance procedures of the Ministry aim to reinforce the effectiveness of the IRS in the workplace. More particularly, it is the Ministry's Occupational Health and Safety Division which has been given the role of propagating and supporting the operation of the IRS.

The essence of the IRS is that all those involved in the operation and conduct of a workplace should accept responsibility for the quality of its health and safety. In order for this system to be effective, the complete line of command, from the board of directors through the chief executive, senior officers and managers, supervisors and workers must accept the commitment to foster and improve health and safety in the workplace.

The IRS is embodied in the Act in a number of important ways, for example, in specifying the duties of employers, the responsibilities of workers for protecting themselves, and the joint duties of employers and workers in legally mandated health and safety committees.

## B.1 Duties of Employers

Sections 14 and 15 of the Act set out a long list of duties for the employer. For example, section 14 states that the employer must ensure that all prescribed equipment, materials, and protective devices are maintained in good condition, and that they are used as prescribed. This section also

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<sup>8</sup>*Occupational Health and Safety Act*, s. 1, par. 6.

<sup>9</sup>The six designated substances are asbestos, coke oven emissions, lead, mercury, isocyanates, and vinyl chloride. The six for which there are proposed regulations are acrylonitrile, arsenic, benzene, formaldehyde, noise, and silica. The Government of Ontario has given notice under s. 41(2), par. 14 of the Act that it intends also to regulate four other substances, namely, cadmium, chromium, ethylene oxide, and styrene.

<sup>10</sup>*Occupational Health and Safety Act*, s. 41.

requires the employer, *inter alia*, to provide information to the worker to protect health and safety; to afford assistance and co-operation to health and safety committees or representatives; to "take every precaution reasonable in the circumstances for the protection of a worker";<sup>11</sup> and to post "... a copy of this Act and any explanatory material prepared by the Ministry, both in English and the majority language of the work place, outlining the rights, responsibilities and duties of workers."<sup>12</sup> Section 15 gives additional duties to the employer, including the establishment of an occupational health service for workers; the keeping and maintenance of accurate records in respect of the use of biological, chemical, or physical agents; and the keeping, maintenance, and availability to the worker affected of his exposure records in respect of such agents. This section also imposes a duty on the employer to comply with any standard "... limiting the exposure of a worker to biological, chemical or physical agents as prescribed."<sup>13</sup>

## B.2 Duties of Workers

The Act requires the worker to take responsibility for his own health and safety in the workplace. A worker's duties, as set out in section 17 of the Act, include conducting his work in compliance with the provisions of the Act and using the equipment, protective devices, or clothing that the employer requires. Moreover, the worker is required to report to his employer or supervisor the existence of any hazard; the absence of, or defect in, equipment or protective devices; and any contravention of the Act or regulations made thereunder. Thus, every worker in effect becomes a front-line health and safety inspector.

Section 23 carries the worker's front-line inspector role beyond that of merely reporting hazards and contraventions to the employer or supervisor. Section 23(3) gives the worker the right to refuse to do work which he has reason to believe is likely to endanger himself or another worker. This provision may be used not only in respect of any specific equipment, machine, or device, but also more broadly in respect of the physical condition of the workplace. A worker who chooses to exercise this right of refusal has a duty to report the circumstances of his action promptly to his employer or supervisor and, if possible, to a worker representative of the health and safety committee, who thereupon must investigate the situation. If, after investigation and any necessary action, the worker still considers the situation to be dangerous, he may continue his refusal, whereupon a Ministry of Labour inspector must be called in. During both the initial in-house investigation and any subsequent inquiry and decision by the Ministry

<sup>11</sup>Ibid., s. 14(2)(g).

<sup>12</sup>Ibid., s. 14(2)(h).

<sup>13</sup>Ibid., s. 15(1)(g).

inspector, section 23(11) stipulates that “. . . no worker shall be assigned to use or operate the equipment, machine, device or thing or to work in the work place or the part thereof which is being investigated unless the worker to be so assigned has been advised of the refusal by another worker and the reason therefor.”<sup>14</sup>

### B.3 Joint Responsibility

The investigation of unhealthy or unsafe work conditions is carried out, in the first instance, by representatives of labour and management together. Such investigation is one of several joint activities that are central to the principle of the IRS. Section 8(2) of the Act mandates the establishment, in workplaces of twenty or more workers, or in any workplaces where a designated substance is present, of a joint health and safety committee. That the committee structure is critically important to the IRS and to Ontario's health and safety system is signalled several times in the Act. First, the Act repeatedly stipulates that in all significant workplaces there must be an institutionalized concern for identifying situations that may be a source of danger or hazard to workers, recommending investigation or specific courses of action, and following-up to ensure that appropriate attention is given to any situation. Second, section 8(5) of the Act states that the joint committee must consist of at least two persons, of whom at least half must be workers; such worker representatives should be selected by the workers or, where applicable, by the relevant union(s). Here the evident intention of the Act is to institutionalize the concept that workers are equally responsible for health and safety along with management. Third, section 8(6) gives the committee “. . . power to . . . obtain information from” employers concerning the identification of potential or existing hazards, and health and safety experiences and practices in similar or other industries. Fourth, section 8(8) gives the worker members of the health and safety committee the power and duty to designate one worker representative to inspect the physical condition of the workplace once a month.<sup>15</sup> Fifth, the joint health and safety committee provides a vehicle whereby Ministry of Labour inspectors get a view of the issues of concern to workers because it is envisaged that a worker representative will accompany an inspector on his plant tour or, absent such a representative, that the inspector shall consult workers during his tour.<sup>16</sup> Sixth, a copy of any orders or reports issued by an inspector must be lodged with the health and safety committee and must furthermore be posted conspicuously in the workplace.<sup>17</sup> The com-

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<sup>14</sup>Ibid., s. 23(11).

<sup>15</sup>These inspections can be carried out more frequently in relation to a critical injury or where a director of the Ministry of Labour so directs. See *Occupational Health and Safety Act*, ss. 8(9) and 23(4).

<sup>16</sup>Ibid., ss. 28(3) and 28(4).

<sup>17</sup>Ibid., s. 29(6).

mittee is thus a vehicle for ensuring follow-up to orders issued during an inspection, and for informing workers at-large about the conditions of their work environment. Finally, the Act states that members of health and safety committees are entitled to take the necessary time from work in order to attend committee meetings and perform prescribed inspection duties. The time so spent is to be considered paid work time, thereby once again indicating that workers' concerns for health and safety are an integral part of daily work activity.<sup>18</sup>

We note that the recommendations of joint health and safety committees are advisory rather than binding; the long-run effectiveness of the IRS therefore hinges upon the quality of the response to this advice.

#### **B.4 The Internal Responsibility System and the Designated Substances Regulations**

Having incorporated the concept of internal responsibility in the Act through the establishment of such institutional arrangements as the joint health and safety committee, the government uses the IRS foundation to ensure compliance with the regulations promulgated for the control of designated substances. These regulations impose requirements on employers to operate within stated exposure limits and to provide respiratory equipment where control limits are exceeded. As well, the regulations extend significantly further to rely on the IRS for the assessment of hazards and the development and implementation of control programmes, including the provision of appropriate medical surveillance. Thus, the Act applies in a special way to designated substances.

We shall consider this special relationship by focusing on the Regulation Respecting Asbestos. This Regulation contains eighteen sections and is currently supplemented by Codes for: Respiratory Equipment for Asbestos; Measuring Airborne Asbestos Fibres; and Medical Surveillance for Asbestos Exposed Workers.

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<sup>18</sup>Ibid., s. 8(12). The language of this section has proved problematic:

. . . Arbitrator Barton in *Perley Hospital and Ontario Nurses Association* (1980), 29 L.A.C. (2d) 178 held that an employee was not entitled to pay when called in on her day off to attend a joint committee meeting. Barton held that this was not time from work and only "time so spent" was to be remunerated. The result can be defended in technical legal terms, for ss. 29(5) (accompaniment of an inspector) and 23(12) (inspection of a work refusal) specifically say that the time spent by a committee member in these situations is "deemed" to be work time. Section 8(12) does not use that magic word. [Morley Gunderson and Katherine Swinton, *Collective Bargaining and Asbestos Dangers at the Workplace*, Royal Commission on Asbestos Study Series, no. 1 (Toronto: Royal Commission on Asbestos, 1981), p. 8.15.]

### (a) The IRS and Assessment

Section 6(1) of the Regulation Respecting Asbestos states that “Every employer to whom this Regulation applies shall cause *an assessment to be made in writing* of the exposure or likelihood of exposure of a worker to the inhalation or ingestion of asbestos.” (Emphasis added.) Section 6(3) stipulates that the employer must consult with the joint health and safety committee in the preparation of this assessment and that the committee may make recommendations on same. Each member of the committee must receive a copy of the employer’s assessment.<sup>19</sup> While the employer does not have to get the approval of the joint committee for the assessment, the joint committee, or a member thereof, has the right to notify a Ministry of Labour inspector in the event of any dispute between the employer and the committee regarding an assessment.<sup>20</sup> The inspector is then obliged to investigate the dispute and give a decision in writing.

### (b) The IRS and the Control Programme

Section 7(1) of the Regulation stipulates that “Where the assessment discloses . . . that a worker is likely to inhale or ingest asbestos and that the health of the worker may be affected thereby,” the employer must establish an asbestos control programme. This programme contains a number of elements which are set out in section 7(2), including engineering controls, work practices, hygiene practices and facilities, methods and procedures for monitoring record-keeping, medical examinations, and clinical tests.

In developing the control programme, the employer is again required to draw on the resources of the IRS by consulting with the joint health and safety committee. The committee may make recommendations regarding the control programme;<sup>21</sup> and the committee, or a member thereof, may notify a Ministry of Labour inspector in the event of a dispute with the employer regarding the asbestos control programme.<sup>22</sup> Once the control programme is in place, the employer is required to furnish each member of the joint health and safety committee with a copy of the programme and to acquaint every worker affected by it with its provisions, both in English and in the majority language of the workplace.<sup>23</sup>

### (c) The IRS and Air Monitoring

The asbestos control programme must include provisions for “methods and procedures to monitor the concentrations of airborne asbestos in

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<sup>19</sup>Regulation Respecting Asbestos, s. 6(4).

<sup>20</sup>Ibid., s. 9(1).

<sup>21</sup>Ibid., s. 7(3).

<sup>22</sup>Ibid., s. 9(1).

<sup>23</sup>Ibid., ss. 10(1) and 10(2).

the work place and the exposure of a worker thereto.”<sup>24</sup> The air monitoring procedures are set out in the Code for Measuring Airborne Asbestos Fibres. Air monitoring results must be conspicuously posted in the plant for fourteen days and furnished to the joint health and safety committee; they must be kept by the employer for a period of at least five years. It seems clear that the joint committee, as the institutionalized embodiment of the IRS, has a central role in ensuring that the ongoing results of air monitoring, critical to the achievement of the lowest practical exposure and to the enforcement of the control limits, are both known and reviewed.

#### (d) The IRS and Medical Surveillance

The asbestos control programme must include provisions for medical examinations and clinical tests of asbestos-exposed workers.<sup>25</sup> These are paid for by the employer.<sup>26</sup> The employer must provide the physician who examines the worker with a copy of the records of the worker’s exposure to airborne asbestos.<sup>27</sup> These records, together with those of the medical examinations and clinical tests, must be kept by the examining physician in a secure place for a period of up to forty years.<sup>28</sup> Where the physician is no longer able or willing to keep the records, they must be forwarded to the Chief Physician of the Ministry of Labour’s Occupational Health Medical Service or his designate.<sup>29</sup>

Here the IRS incorporates another participant, the physician. Whether company physician or independent practitioner (a subject to which we shall return later in this chapter), the Regulation requires the physician to accept his own individual responsibility in the system.

## C. The Role of the Ministry of Labour

### C.1 The Occupational Health and Safety Division

The *Occupational Health and Safety Act* vests the government’s responsibility for the health and safety of workers in Ontario in the Ministry of Labour, more specifically, in the Ministry’s Occupational Health and Safety Division. This Division was assembled in 1976 from elements of the Ministries of Health, Natural Resources, and Labour to consolidate all provincial activities in occupational health and safety. The Division is led by an Assistant Deputy Minister, an Executive Director, and six Branch Directors.

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<sup>24</sup>Ibid., s. 7(2)(b).

<sup>25</sup>Ibid., s. 7(2)(d).

<sup>26</sup>Ibid., s. 13(1).

<sup>27</sup>Ibid., s. 14(2).

<sup>28</sup>Ibid., s. 15(1).

<sup>29</sup>Ibid., s. 15(2).

The Division's total complement is reportedly 732.<sup>30</sup> The Division is asked to provide the policy direction for the province with respect to the identification of potential hazards and the establishment of legislative standards, and to meet the day-to-day needs of the province for support, inspection, and enforcement with respect to healthy and safe workplaces.

Three branches of the Division — the Industrial Health and Safety Branch, the Mining Health and Safety Branch, and the Construction Health and Safety Branch — are primarily involved in developing and delivering health and safety field services to workers and employers. These services include “. . . inspection of work premises and practices for compliance with the health and safety legislation; advising and counselling employers, workers and suppliers of materials and equipment on the requirements of the legislation and more generally on health and safety concerns; enforcing the legislation; maintaining descriptive records of Branch activities and the problems dealt with; and contributing to the development of policy and legislation.”<sup>31</sup>

The Industrial Health and Safety Branch is reported as employing 184 people, including 167 field staff. The Branch is decentralized into five administrative areas with twenty regions.<sup>32</sup> It has responsibility for all manufacturing, service, trade, transportation, storage, communication, and whatever other work sites are not covered by the Construction or Mining Branches or by federal health and safety legislation. In fact, approximately 150,000 industrial establishments in Ontario come under the jurisdiction of the Industrial Health and Safety Branch. In the period April 1, 1982 to March 31, 1983, the Branch made 46,480 inspections,<sup>33</sup> issued 56,435 orders, reviewed 1,962 plant submissions, investigated 118 refusals to work, and prosecuted 73 cases.<sup>34</sup>

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<sup>30</sup>Information in this section is drawn largely from Ontario, Ministry of Labour, “Annual Report 1982–1983,” Draft. Statistical information is given for the period April 1, 1982 to March 31, 1983.

<sup>31</sup>Ontario, Ministry of Labour, Written submission to the Royal Commission on Asbestos, #43, February 1981, pp. 27, 31.

<sup>32</sup>Ontario, Royal Commission on Asbestos, Transcript of Public Hearings [hereafter RCA Transcript], Evidence of Mr. Walter Melinyshyn, 22 June 1982, Volume no. 43(A), p. 6.

<sup>33</sup>Each industrial establishment is on a regular inspection cycle ranging from once every three months to once every thirty-six months, depending on its record of accidents and fatalities, the number and nature of orders issued during inspections, labour-management relations, work refusals, etc. Inspection frequency can be increased or decreased on the advice of an inspector and approval of the regional manager. In addition to the above-noted cyclical reviews, known as Code 1 Internal Responsibility System inspections, inspectors can visit plants for other reasons, such as to check on the follow-up procedures to orders issued (Code 3); to make special calls, for example, in the event of a work refusal (Code 5); or to investigate accidents (Code 7).

<sup>34</sup>See also, RCA Transcript, Evidence of Mr. Walter Melinyshyn, 22 June 1982, Volume no. 43(A), pp. 5–15.

The Construction Health and Safety Branch is reported as employing 117 people, including 103 inspectors, with concerns for construction, renovation, and demolition activities of all types of structures such as buildings, tunnels, highways, and sewers. In fiscal 1982-1983, this Branch made 60,993 inspections, issued 24,378 orders, investigated 5 refusals to work, and prosecuted 245 cases.

The Mining Health and Safety Branch is reported as employing 94 people, including 27 inspectors, with concerns for some 700 mines, metallurgical plants, clay, shale, and peat workings, diamond drilling operations, and quarries, plus approximately 5,500 sand and gravel pits. In fiscal 1982-1983, this Branch carried out 5,673 inspections, issued 4,712 orders, investigated 13 refusals to work, and prosecuted 6 cases.

The field inspectors of the above three branches have a front-line role in ensuring compliance with the Act and the regulations made thereunder. They exercise their authority to enforce compliance by issuing orders pursuant to specific statutory and regulatory provisions.

An important part of an inspector's skills involves knowing when he needs to call on special assistance from the Division. In matters relating to occupational health, the inspector can draw on the support and expertise of the Occupational Health Branch of the Division. This is a staff branch of 187 people, most of whom are technical and professional personnel. The Branch includes the Occupational Health Medical Service, Occupational Health Hygiene Service, and Occupational Health Laboratory. The professional positions are filled by physicians, nurses, radiologists, occupational hygienists, engineers, toxicologists, scientists, and technicians. Inspectors can draw on any of the resources within this Branch simply by so requesting. For example, a physician may be asked to make a field visit to a plant and report to the Industrial Health and Safety Branch regarding the status of its medical surveillance programme. An engineer may be asked to look at problematic ventilation in a plant. In cases where the inspector requests an assessment of dust conditions in the plant, Occupational Health Branch hygienists will take samples and prepare an exposure assessment report.

The Occupational Health and Safety Division is rounded out by two other staff branches. The Special Studies and Services Branch has a complement of 68 people, including 15 involved in the Health Studies Service. This Branch is project-oriented, with assignments that focus on health and safety problems in specific industries or groups of workers, such as Dr. Murray M. Finkelstein's studies of mortality and morbidity among asbestos workers.<sup>35</sup> The Standards and Programs Branch has a complement of 73

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<sup>35</sup>See, for example, Murray M. Finkelstein, "Mortality Among Long-Term Employees of an Ontario Asbestos-Cement Factory," *British Journal of Industrial Medicine* 40 (1983): 138-144.

people, including more than 40 professional staff. "This Branch is responsible for the development, co-ordination and evaluation of . . . the [Division's] policies and programs."<sup>36</sup> In relation to asbestos, this work has included the development of the Regulation Respecting Asbestos, and the development of training programmes and manuals for the field force.

## C.2 The Ministry of Labour and the Internal Responsibility System

The Ministry, through its Occupational Health and Safety Division, deploys over 700 people in the goal of worker health and safety. This number is small when ranged against the estimated 170,000 workplaces in the province, many of them operating 7 days a week, 24 hours a day. Some plants are so large and diverse that detailed scrutiny of their operations would consume many days of inspector time.

In this setting, advocacy of the IRS is viewed by the Ministry as an essential tool of compliance. Even prior to the proclamation of the Act, Ministry inspectors were spending a good part of their time trying to convince parties at the workplace to take responsibility for health and safety. When the Act was proclaimed, more and more of the Ministry's activity focused on institutionalizing the IRS in Ontario industry.

Initially, Ministry inspectors spent a good deal of time helping companies set up joint committees and explaining their functions and responsibilities. Before the IRS was institutionalized, an inspector would arrive unannounced at a workplace, advise the plant manager or another senior officer of his intentions, begin an inspection, issue orders as necessary in a meeting with management, and return to see that the orders were complied with. Now, the routine has changed. The inspector still arrives unannounced, but now he must contact both the employer and the worker representatives of the joint committee and interview them to determine if there are any outstanding health and safety concerns so that these can become focal points of his inspection. The representatives accompany the inspector on the tour of the plant.<sup>37</sup> It is hoped that workers can see their representative(s) raising concerns, answering questions, and otherwise assisting the inspector to do his job. Then, in the words of a Ministry official, "The final part of an inspection consists of a discussion of the concerns, suggestions, and orders issued with worker and employer representatives, and a review of the existence and functioning of a joint health and

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<sup>36</sup>Ontario, Ministry of Labour, Written submission to the Royal Commission on Asbestos, #43, February 1981, pp. 35-36.

<sup>37</sup>*Occupational Health and Safety Act*, s. 28(3).

safety committee.”<sup>38</sup> During this discussion, the inspector will review the minutes of the last health and safety committee meeting and, if some committee recommendations have not been dealt with, he will try to ascertain the cause. “Where a specific recommendation is made that the employer does not act upon, and the recommendation concerns a breach or contravention of the Act or a regulation, a Ministry inspector, on being notified, can investigate and may issue an order where there are contraventions of the Act or regulations.”<sup>39</sup> The inspector also, of course, raises his own concerns with the committee and gives a copy of his inspection report to the committee.

The inspection report includes orders issued to the company for contraventions of particular sections of the Act or of the regulations. The company is expected to fill out a Ministry of Labour “Order Follow-up” form indicating status of compliance with outstanding orders. The Ministry of Labour has recently made some administrative reforms in this area with respect to industrial establishments. Whereas the “Order Follow-up” forms used to be mailed to the employer thirty days after the inspection for completion regarding the status of those orders not yet complied with, these forms are now handed to the employer by the inspector before he leaves the premises. Moreover, whereas these forms used to be signed only by management upon completion, the Ministry is now encouraging the practice of securing the co-signature of a worker representative of the joint committee.<sup>40</sup> The latter is in response to concerns expressed by labour that “Order Follow-up” forms sometimes erroneously or prematurely report completion of orders.

The change in the inspector’s routine and the responsibility placed on the joint committee to evaluate and make recommendations on conditions in the workplace, and to monitor compliance with orders, are intended to support the IRS and in turn to reinforce occupational health and safety.

The Ministry of Labour has also changed the way in which its technical staffs operate in relation to the IRS. In testimony before this Commission, a Ministry official noted that, before the Act, the Ministry would routinely monitor the air in industrial establishments where certain substances were known to be used. Since the passage of the Act, the

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<sup>38</sup>RCA Transcript, Evidence of Mr. Walter Melinyshyn, 22 June 1982, Volume no. 43(A), p. 9.

<sup>39</sup>Ontario, Ministry of Labour, Occupational Health and Safety Division, *A Guide for Joint Health and Safety Committees and Representatives in the Workplace* (Toronto: Ontario Ministry of Labour, 1983), pp. 19–20.

<sup>40</sup>Ontario, Ministry of Labour, Memorandum from Ms. Pat C. Coursey, Staff Administrator, Industrial Health and Safety Branch to All Administrators and Operational Improvements Committee, Industrial Health and Safety Branch and Mr. J. Waterman, Standards and Programs Branch, 17 May 1983, pp. 10–11.

establishment of joint committees in those sites that the Ministry had been monitoring, and the initiation of control programmes under the Regulation Respecting Asbestos, the Ministry has slowly changed its system to one where the company takes primary responsibility for air sampling and monitoring, with the Ministry performing an auditing role.<sup>41</sup> Likewise, the roles of the employer and of the joint committees in devising aspects of the control programme which deal with work and hygiene practices and with medical examinations have resulted in a devolution of the primacy once held by the Ministry of Labour, and hence represent a clear transfer of duties to the workplace in these areas.

Beyond its activities directly in support of the IRS, the Ministry is responsible, in the last analysis, for enforcing the Act and regulations. Some of the complaints about the Ministry deal with the emphasis that the Ministry places on supporting the IRS at the expense of initiating prosecutions for violations of the legislation. Nevertheless, the Ministry does lay charges to enforce compliance and to deal with parties whose offences may have contributed to serious injury or fatalities.

We have received data which indicate that between April 1, 1980 and October 31, 1982, the Ministry of Labour launched 817 prosecutions and secured convictions in 666 of them, thus yielding an average success rate of 81.5%. The average fine levied against companies in successful prosecutions in that period was about \$2,000. However, a telling instance of the extent to which the courts are beginning to take a severe view of violations came in December of 1982 when the Ontario Court of Appeal upheld a fine of

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<sup>41</sup>RCA Transcript, Evidence of Mr. Gyan S. Rajhans, 21 June 1982, Volume no. 42(A), pp. 17, 71-72.

\$12,000. The Ministry has stated that "Since this decision, trends indicate higher fines on first conviction."<sup>42</sup>

From the prosecutions data we have reviewed, it is apparent that most of the charges have been in the area of safety rather than health. This may or may not be explained by the recency of the designated substances regulations; the effective enforcement of such regulations is a matter of major concern which we address below.

## **D. The Internal Responsibility System: Problems and Prescriptions**

### **D.1 The IRS as the Foundation of Occupational Health and Safety**

Our specific concern is, of course, asbestos and in particular the protection of workers from any adverse effects resulting from exposure to this substance. If we are concerned about the Internal Responsibility System generally, this is because it provides the foundation for Ontario's strategy to protect workers from asbestos exposure. Numerous complaints brought forward at our hearings indicate that this foundation is not yet regarded as secure.

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<sup>42</sup>Ontario, Ministry of Labour, "Current Issue Memorandum," 12 April 1983. See also, *Regina v. Cotton Felts Limited* (1982), 2 C.C.C. (3d) 287. While the upholding of a \$12,000 fine has had the salutary effect indicated by the Ministry, the language used by the Ontario Court of Appeal is also instructive regarding the seriousness of breaching the *Occupational Health and Safety Act*. As Blair, J.A., speaking for the court, stated in his reasons at 293-294:

Since, as far as we are aware, this is the first appeal against sentence under the Act to reach this court, it is incumbent on us to consider the proper principles governing the imposition of fines for this type of offence. As my brothers and myself made clear during argument, the range of fines imposed by the county court appears inordinately low for these offences . . . .

The *Occupational Health and Safety Act* is part of a large family of statutes creating what are known as public welfare offences. The Act has a proud place in this group of statutes because its progenitors, the Factory Acts, were among the first modern public welfare statutes designed to establish standards of health and safety in the work place. Examples of this type of statute are legion and cover all facets of life ranging from safety and consumer protection to ecological conservation. In our complex interdependent modern society such regulatory statutes are accepted as essential in the public interest. They ensure standards of conduct, performance and reliability by various economic groups and make life tolerable for all. To a very large extent the enforcement of such statutes is achieved by fines imposed on offending corporations. The amount of the fine will be determined by a complex of considerations, including the size of the company involved, the scope of the economic activity in issue, the extent of actual and potential harm to the public, and the maximum penalty prescribed by statute. Above all, the amount of the fine will be determined by the need to enforce regulatory standards by deterrence . . . .

Organized labour has been especially critical of the IRS and made its views clear to us in its written and oral submissions. Labour feels that the concept is deceptive in that it has an appearance of protecting workers, while in practice it provides both management and the government with an excuse for doing as little as possible. Specifically, labour is critical that the committees may appear to give workers an involvement in health and safety while denying them the power actually to accomplish anything. Labour is also concerned that the Ministry uses the IRS to avoid the necessity of action. Labour claims that Ministry officials respond to problems in the workplace by telling the two sides — management and labour — to work difficulties out together. Labour claims that the powerlessness of workers in a “work it out yourselves” situation results in what is, in effect, collusive inaction between management and the government.<sup>43</sup>

The most important institutional arrangement in the IRS is the joint health and safety committee. The joint committee is the specific forum that brings management and labour together. The long-term success of the IRS depends on the successful operation of the joint committee. Spokesmen involved with such committees report the need for patience, commitment, and time. Even in an organization like Ontario Hydro where the commitment to worker protection extends from the Board of Directors to the workplace and where joint committees were in operation prior to the proclamation of the Act, the joint committees do not always work well. In fact, Ontario Hydro reported that a survey of joint committee members found that only 4 of 30 management and labour representatives felt that their committees worked “very well.”<sup>44</sup> In other workplaces the situation may be less successful.

The study prepared by Professor Morley Gunderson and Professor Katherine Swinton for this Commission provided a review of the operation of joint health and safety committees:

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<sup>43</sup>See, for example, RCA Transcript, Submission by Mr. Robert Stewart on behalf of the Energy and Chemical Workers Union, 16 February 1981, Volume no. 1, p. 76; RCA Transcript, Submission by the Canadian Union of Public Employees, Local 27; and the Windsor Occupational Safety and Health Council, 27 March 1981, Volume no. 6, pp. 12-25; and RCA Transcript, Submission by Ms. Linda Jolley on behalf of the Ontario Federation of Labour, 28 January 1983, Volume no. 58, pp. 59-60. See also, *Canadian Occupational Health and Safety News* 6:2 (17 January 1983), p. 3; Cameron Wright, LeeAnne Mullis, and Lori Maynes, *Peterborough Toxics Profile* (Peterborough: Ontario Public Interest Research Group, Trent University, 1982); Elie Martel, “Not Yet Healthy, Not Yet Safe,” a speech in the Ontario Legislature by Elie Martel, MPP, Chairman, Ontario New Democratic Task Force on Occupational Health and Safety, 26 April 1983; and Letter from Ms. Linda Jolley on behalf of the Ontario Federation of Labour to the Royal Commission on Asbestos, 31 January 1983.

<sup>44</sup>Ontario, Royal Commission on Asbestos, Exhibit II-56, Tab 8 [hereafter RCA Exhibit], in RCA Transcript, Evidence of Mr. Robert Wilson, 15 June 1982, Volume no. 40(B), p. 14: Presentation to the Royal Commission on Asbestos on the Internal Responsibility System in Ontario Hydro and Experience with Asbestos, Toronto, 15 June 1982, p. 10 and Table 2.

An assessment of the efficacy of the joint health and safety committees is difficult to make, as the experience has been limited and empirical evidence of their operations is virtually non-existent. Some cautious generalizations may be attempted, but with the caveat that experience will vary in the 25,000 committees under the legislation. . . . Factors affecting operation will include the age of the committee, frequency of turnover of representatives, the financial position of the company, the general industrial relations climate, and the types of hazards in the workplace.<sup>45</sup>

The effectiveness of joint health and safety committees may vary depending upon whether the workers are organized or unorganized. Gunderson and Swinton have suggested that without the support provided by a labour organization, workers may find it very difficult to take advantage of the rights given to them under the Act and to exercise their responsibilities as members of a health and safety committee.<sup>46</sup> Further, where workers are not organized in unions, they are likely to be either uninformed of their rights or reluctant to use them fully. Ministry of Labour officials corroborated during our hearings that special efforts are required to make unorganized workers more effective participants in the internal responsibility approach to compliance.<sup>47</sup> In particular, the concept of the worker as an auditor of the workplace is less compelling where the individual does not feel protected by a union.<sup>48</sup>

The matter of labour organization aside, other circumstances can affect the degree of worker participation. In their study for this Commission, Professor Sally Luce and Professor Gene Swimmer pointed out that the operation of joint committees may be less effective where English is not the predominant language in the workplace, or where a variety of languages are spoken, thus impeding communication among workers and between workers and their representatives on the health and safety committee. In addition, worker involvement may be constrained where workers are culturally reluctant to "get involved," or where workers are transient and relatively unskilled.<sup>49</sup>

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<sup>45</sup>Gunderson and Swinton, *Collective Bargaining and Asbestos Dangers at the Workplace*, p. 8.10.

<sup>46</sup>*Ibid.*, p. 8.21.

<sup>47</sup>RCA Transcript, Evidence of Mr. Walter Melinyshyn, 22 June 1982, Volume no. 43(A), pp. 50, 54.

<sup>48</sup>RCA Transcript, Evidence of Mr. Arthur L. Gladstone, 30 June 1982, Volume no. 47(A), pp. 105-106.

<sup>49</sup>Sally Luce and Gene Swimmer, *Worker Attitudes About Health and Safety in Three Asbestos Brake Manufacturing Plants*, Royal Commission on Asbestos Study Series, no. 6 (Toronto: Royal Commission on Asbestos, 1982), pp. 6.2-6.3.

In addition to problems of participation by workers, there are clearly problems at the management level. Management's concern about health and safety is variable among workplaces. Some are highly concerned; some less so. Where management is less concerned, the seed of internal responsibility will have more difficulty germinating. As well, management's propensity to consult workers can be highly variable.

The problems we have referred to above affect all aspects of the operation of joint health and safety committees, not only their effectiveness in dealing with designated substances. Solutions to these problems should be designed with a complete view of the full range of responsibilities assigned to these committees. The details of such solutions lie well beyond our terms of reference. Inasmuch as the general effectiveness of the Internal Responsibility System is the all-important foundation of measures intended to protect workers from hazards of asbestos, we urge the Ministry of Labour to undertake a systematic review of the operation of the joint health and safety committees. We note that the Advisory Council on Occupational Health and Occupational Safety has struck a task force on the *Occupational Health and Safety Act*, including the operation of the joint committees. We further note that the recent Task Force on Occupational Health and Safety of the Ontario New Democratic Party, which catalogued a number of serious problems, concluded among other things "... that the Internal Responsibility System as it now exists only works when the company and the union are equally committed to making it work."<sup>50</sup> Similar views were expressed at our hearings and lead us to emphasize the importance, in any Ministry review of joint committees, of seeking to identify instances in which joint committees have operated successfully, the factors that account for this success, and the extent to which the labour and management participants in successful operations can contribute to the dissemination of information to other workplaces by acquiring a role in training programmes or by other means. In line with these considerations, we recommend that:

- 8.1 The Ministry of Labour should undertake to identify instances of the successful operation of joint health and safety committees and the means whereby the factors that account for this success can be disseminated through information and training programmes, drawing upon the review by the Advisory Council on Occupational Health and Occupational Safety and such other analyses as are necessary.*

## **D.2 The IRS and Training**

Training has long been recognized as a key adjunct of occupational health and safety, particularly in the realm of accident prevention. The new

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<sup>50</sup>Martel, "Not Yet Healthy, Not Yet Safe," p. 8.

and welcome emphasis on health augments the need for training. In addition, the premium that the IRS places on joint labour-management involvement in the health and safety of the workplace invites joint rather than separate training programmes. In this regard, current training efforts in Ontario strike us as lagging behind the basic philosophy of internal responsibility.

Training programmes are available relating to worker health and safety through the Accident Prevention Associations, which are funded by the Workers' Compensation Board. It has been submitted to us, however, that labour does not place its full confidence in the Accident Prevention Associations, viewing them as being biased towards management.<sup>51</sup> There is thus some suspicion of training programmes offered through these associations. Meantime, the Ontario Federation of Labour (OFL) has developed training programmes of its own, which have received substantial usage. The OFL has informed us of more than a dozen workplaces where OFL training for worker health and safety has been used, including General Motors of Canada Limited, Northern Telecom, American Can Corporation, and Algoma Steel. These training programmes were offered in many cases to management as well as to labour. The OFL training programmes are supported in part by the Ministry of Labour, through its apportionment from the profits of the Ontario Lottery Corporation.

It may be that fundamental reform of the Accident Prevention Associations is required if labour is to have full confidence in these associations. We understand that the Advisory Council on Occupational Health and Occupational Safety has recommended to the Minister of Labour that representation on the Council of Safety Associations be altered to achieve a balance between labour and management, and that the Council of Safety Associations be encouraged to enter into appropriate arrangements with labour and the Accident Prevention Associations to develop occupational health and safety training programmes jointly run by management and labour.<sup>52</sup> We view the organization of the safety associations as a matter that lies beyond our terms of reference, and note that Professor Paul C. Weiler will be addressing it in a future report to the Minister of Labour on workers' compensation.<sup>53</sup>

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<sup>51</sup>RCA Transcript, Submission by Mr. Ed Hunt on behalf of the United Electrical, Radio and Machine Workers of America, 20 February 1981, Volume no. 5, p. 86.

<sup>52</sup>Ontario, Ministry of Labour, Advisory Council on Occupational Health and Occupational Safety, "Advisory Memorandum 81-II on Prevention in Occupational Health and Safety Through the Workmen's Compensation Board and its Accident Prevention Associations," in *Fourth Annual Report, April 1, 1981 to March 31, 1982* (Toronto: ACOHOS, 1982), pp. 57-70, especially Recommendations 81-6 and 81-7, p. 67.

<sup>53</sup>Paul C. Weiler, *Protecting the Worker from Disability: Challenges for the Eighties*, a report submitted to Russell H. Ramsay, Minister of Labour ([Toronto: Ontario Ministry of Labour], April 1983), p. 5.

Nevertheless, we do believe that a training structure more in keeping with the joint philosophy of the IRS might result from giving further encouragement to management and labour to design their own co-operative training programmes when they feel this would better serve the needs of their workers than programmes currently offered by the Accident Prevention Associations. In this connection, we note that the *Workers' Compensation Act* applies levies on employers which do not take account of the cost of training programmes that have been mounted outside the framework of the associations in co-operation with labour. In order to encourage the development of joint programmes that are in line with the philosophy of the IRS, we consider it highly desirable that employers who choose to organize training courses in full concert with labour unions should enjoy a reduced assessment. This simple step would likely multiply the number of joint training programmes. Accordingly, we recommend that:

- 8.2 *The Workers' Compensation Act should be amended to provide that where an employer establishes or contributes from his own resources to the financing of a joint labour-management programme for the purpose of education in accident or disease prevention, and the Board is satisfied that the programme is serving the same purpose as an Accident Prevention Association programme, the Board may reduce the assessment for which the employer is liable as a member of a class represented by an Association.*

Whatever the auspices under which training programmes are offered, it is critically important that members of joint committees take advantage of the training opportunities that are available. The Ontario Federation of Labour made a particularly strong point about the training that is necessary if worker representatives on joint committees are to be equipped to deal with health as distinct from safety issues. In the absence of training, workers may be quite unable to carry on effective dialogue with technically qualified management representatives on such health issues as the identification of hazardous substances, the particular hazards they pose, the need for improved measures of control, and the practicality of alternative control measures. Furthermore, workers coming directly off the shop floor may be unfamiliar with the skills and techniques of effective committee work. For both the substance of health issues and effective participation in joint committees, labour representatives in particular need to take advantage of the training opportunities that are available.

This raises the question of whether labour representatives on joint committees should receive pay while attending training courses. Under section 8(12) of the *Occupational Health and Safety Act*, a committee member is only paid for such time from his work as is necessary to attend committee meetings, conduct a periodic inspection of the workplace, or investigate a serious accident. We consider it beyond our terms of reference to address the matter of paid time for health and safety training in general,

but well within our mandate to consider the issue of paid time for training with an occupational health content in workplaces where a designated substance such as asbestos is present. We accept the validity of the contention of the OFL that occupational health training is particularly necessary if labour representatives are to participate effectively in the work of joint committees. The presence in the workplace of a substance which, like asbestos, has been deemed sufficiently hazardous to warrant designation in our view justifies paid time for worker training. Given an enabling clause in the legislation, the place in which to make this stipulation is the appropriate designated substance regulation. Accordingly, we recommend that:

- 8.3 *The Occupational Health and Safety Act should be amended to provide that, where stipulated by regulation, members of a joint health and safety committee may be entitled to paid time from work for the purpose of occupational health and safety training; the Regulation Respecting Asbestos should be amended to stipulate that members of joint health and safety committees shall be entitled to paid time from work for the purpose of occupational health training in programmes approved by the Minister.*

### D.3 The Importance of Informed Workers

The Act places considerable onus on workers to serve as their own health and safety inspectors to ensure compliance with legal requirements and more particularly the absence of any situation likely to endanger their health and safety in the workplace. The Regulation Respecting Asbestos attempts to equip workers to exercise this responsibility by requiring that employers "... acquaint every worker affected by the asbestos control program with its provisions."<sup>54</sup> This provision is intended to ensure that workers are aware of, for example, the importance of ventilation equipment, dust covers, and respirators and should, in keeping with the Act, allow the worker to avoid situations likely to endanger his health. But the worker would be even better equipped to avoid danger if he were aware of the nature of the hazard.

This matter is covered in part by the Code for Medical Surveillance which accompanies the Regulation. Section 5 of the Code, entitled Health Education, prescribes that at the pre-placement and periodic medical examinations all workers are to be "... advised of the hazard from asbestos and smoking. . . ." Nowhere, however, does the Regulation stipulate that workers are to be informed about the starkest fact concerning asbestos-related disease: the existence of a dose-response relationship. We attach the greatest importance to ensuring that every asbestos worker should know that the lower the exposure to asbestos, the lower the risk of disease.

<sup>54</sup>Regulation Respecting Asbestos, s. 10(1).

As we stated at the beginning of this chapter, what we regard as fundamental to the matter of control limits is the duty which the Regulation imposes on every employer to take all necessary measures to ensure that exposure to asbestos "is reduced to the lowest practical level." This means that the control limits are not norms but maxima; the employer's obligation is to conform to what is commonly called the ALARA principle (As Low As Reasonably Achievable). We appreciate the point made at our hearings by counsel for the Asbestos Victims of Ontario and the Iron Workers' Union, Mr. David Starkman, that it would be very difficult for the Ministry to prosecute an employer for failing to achieve the lowest practical level if in fact all measurements met the numerical control limit.<sup>55</sup> It follows that if the ALARA principle is to have any operational significance, workers must be aware that it is part of the law, so that they can, through their joint health and safety committees, insist on the performance the Regulation requires. It is therefore crucial that workers be made aware of this provision, which we believe has regrettably drawn far less attention than the numerical control limits. The Act and regulations focus communications on the joint committee rather than on rank and file workers. Thus, it is generally left to labour and management, as part of the IRS, to inform workers of their rights and responsibilities.

In this setting, we conclude that it is imperative that the Regulation Respecting Asbestos stipulate that an essential element of every control programme should be to inform workers of both the existence of a dose-response relationship and of the fact that the Regulation establishes the duty of the employer to ensure that exposure to asbestos is reduced to the lowest practical level. We therefore recommend that:

*8.4 The Regulation Respecting Asbestos should be amended so as to require that every asbestos worker shall be informed of:*

- (i) the existence of a dose-response relationship for asbestos-related disease, namely, the lower the exposure, the lower the risk of disease; and*
- (ii) the fact that the Regulation establishes control limits as maxima and imposes on the employer the duty to take all necessary measures and procedures to ensure that the time-weighted average exposure of a worker to airborne asbestos is reduced to the lowest practical level.*

In the ongoing reality of the workplace, the operational effectiveness of the ALARA principle will hinge in large part on the capacity of employers and workers to observe the behaviour of measured exposure levels over time. Are these levels steady, declining, or drifting upwards? To

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<sup>55</sup>RCA Transcript, Submission by Mr. David Starkman on behalf of the Asbestos Victims of Ontario and the International Association of Bridge, Structural and Ornamental Iron Workers, Local 721, 28 January 1983, Volume no. 58, p. 17.

answer this question requires that it be possible to compare dust levels at any particular time with previously existing dust levels. This requirement has implications for deciding what air sampling to undertake, how to summarize the results of that sampling, and how to present the results.

We have analyzed the hygiene data taken by the Ministry in an Ontario asbestos manufacturing plant over a period of several years. These data revealed considerable variations in dust levels from one work station to another, from one process in the plant to another, and from one measurement date to another. These considerable and significant variations mean that a single average dust level calculated for a plant at a particular time is not especially meaningful. The average would depend very much on where samples were taken, as well as on the other factors that cause variability in dust levels. If current readings are to be compared with past ones, this must be done separately for each area of the plant that has significantly different dust levels. Furthermore, a meaningful comparison can only be made when a number of samples are available, because of the high degree of variability from one sample to another. This requires that the several samples taken in a particular area of a plant be summarized, by calculating the average, median, or geometric mean of those samples, to yield a single statistic that may be compared with the corresponding statistic for previous periods. In Chapter 7 we present what appears to be the appropriate summary statistic,<sup>56</sup> but careful study might reveal that some other summary statistic would better represent highly variable data such as these.

Once such a summary can be presented for each relevant area of the plant for each air quality assessment in the plant, there is still the question of how successive summary statistics can be compared with each other. A simple comparison would be to maintain a plot or graph of these data over, for example, a one- or two-year period. This is probably desirable. Once again, however, the variability of the data means that any given assessment statistic may be strongly influenced by random variations. A more precise test of whether air quality for a given period is in fact worse or better than that of the recent past would be to compare a weighted average of the statistics from the last few periods, with declining weights attached to the early readings, to the average for the previous year or two. Such a comparison would avoid generating alarm when random events cause the readings to increase, while simultaneously signalling persistent upward trends in the data. We believe that information such as that just discussed should be prepared for each asbestos-using plant on a regular basis, and posted for a considerable period of time for the information of both workers and management. Accordingly, we recommend that:

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<sup>56</sup>See Chapter 7, Section B.4 and note 18 therein.

**8.5** *Section 12 of the Regulation Respecting Asbestos should be amended to require that each time monitoring of airborne asbestos takes place, an appropriate summary statistic of the resulting fibre concentrations be calculated for each area of the plant, where areas are defined as portions of the plant in which dust levels are reasonably similar. The results for each area to be posted under section 12 should include these summary statistics. In addition, a summary of the average dust level in each area over the past one or two years should be calculated and compared with the current dust levels and with a weighted average of recent dust levels. The results of the monitoring and of this analysis should be posted as specified in section 12(a), but for a period of at least two months, or until rendered obsolete by subsequent measurements, rather than for the fourteen-day period specified in the existing Regulation.*

Another problem with the sampling aspect of a monitoring programme arises from the need to ensure that the equipment is properly calibrated and that the use of the equipment is such that the resulting fibre counts are fair and representative measures of the dust concentrations to which the worker is exposed. This requires a reasonable degree of competence and good intentions on the part of the individual responsible for conducting or supervising the air monitoring programme. It also requires that workers should feel assured that the proper procedures are in fact being followed. In line with the philosophy of the IRS, we shall first address the requirement of ensuring the competence of the individual responsible for supervising the air monitoring programme and then the importance of worker assurance.

The former is a straightforward matter of acceptable qualifications. Here the Regulation Respecting Asbestos presents a curious anomaly as between its Code for Medical Surveillance and its Code for Measuring Airborne Asbestos Fibres. Because the Medical Surveillance Code refers to the role of the examining physician, it automatically ensures that this role will be filled by an individual with accredited professional qualifications. The Measurement Code, on the other hand, contains instructions at a level of technicality such that they could only be understood by a trained individual, but makes no reference whatsoever to what kind of individual might possess the necessary qualifications. The Regulation therefore appears to assume that qualified individuals will be in charge of air monitoring, and presumably leaves detection of unsuitable work by unqualified individuals to the inspection process.

We consider this to be less than satisfactory. In respect of each plant with an asbestos control programme, there should be an individual with designated responsibility for designing representative air sampling procedures, for seeing that the Code for Measuring Airborne Asbestos Fibres is respected, and for ensuring that equipment is properly calibrated. This

individual should be certified as competent by the Occupational Health and Safety Division of the Ministry of Labour and liable to the loss of his certificate if the findings of inspectors so warrant. We permit ourselves to hope that the initial issuance of certificates could be simply a matter of having the Occupational Health Hygiene Service endorse the qualifications which the individuals now in charge of asbestos air monitoring in plants, whether as employees or contracted professionals, already possess. If this hope proves unfounded, the rationale for our prescription is that much stronger. We therefore recommend that:

**8.6** *The Regulation Respecting Asbestos should be amended so as to require that in every plant with a control programme, there shall be an individual certified by the Occupational Health Hygiene Service who will be designated as responsible for designing representative air sampling procedures; for seeing that the Code for Measuring Air-borne Asbestos Fibres is respected; and for ensuring that equipment is properly calibrated.*

In the matter of worker assurance that air monitoring is being suitably implemented, we are mindful of the extent to which certain aspects of air sampling are sufficiently complex to baffle lay-persons. This, of course, argues in favour of the certification we have prescribed. On the other hand, there are aspects of air monitoring (notably, observing the proper calibration of equipment and the question of where to sample and when) for which lack of technical qualifications is not a barrier to worker participation.

We attach importance to a worker role at the level of observing calibration and suggesting what portions of a plant's operations should be included in a representative air sampling programme. With respect to the latter, a worker's first-hand knowledge of conditions on the plant floor can be particularly valuable. While all the worker members of a joint health and safety committee can be potentially of assistance, we look as a practical matter to a particular role for the worker representative who, pursuant to section 8(8) of the Act, must be designated to make periodic inspections of the workplace. It is desirable, as we point out in Chapter 7, to include worker representatives in the task of fibre counting. (See Recommendation 7.8.) Whether or not there is worker involvement in this task, the Regulation should require that the worker representative appointed pursuant to section 8(8) of the Act observe the calibration of air sampling equipment and be consulted with respect to what constitutes representative air sampling. On the basis of these activities, the worker representative will likely promote informed discussion at the level of the joint committee and be a source of reassurance to his fellow members on the committee. His role will in some ways parallel that of the worker representative in mines, concerning which *The Report of the Joint Federal-Provincial Inquiry Commission into Safety in Mines and Mining Plants in Ontario* (the Burkett Report) com-

mented at some length. This is appropriate in that a designated substance workplace, like a mine, warrants special precautionary measures. In this regard, we note that the Burkett Report recommended that the worker representative in mines should be afforded preparation time, together with office and secretarial assistance, so as to enhance his effectiveness,<sup>57</sup> and register our considered opinion that the same should apply in workplaces in which asbestos is present. In line with these considerations, we recommend that:

**8.7 *The Regulation Respecting Asbestos should be amended to require that the worker representative appointed pursuant to section 8(8) of the Occupational Health and Safety Act:***

- (i) *have the opportunity to observe, on his plant tour, the calibration of air monitoring equipment;*
- (ii) *be consulted on the adequacy of representative air sampling procedures; and*
- (iii) *be afforded preparation time, together with office and secretarial assistance, beyond that already recognized for the preparation of minutes of committee meetings.*

#### **D.4 The IRS and the Role of Management**

The critical importance which we attach to the ALARA principle that is embodied in the Regulation Respecting Asbestos leads us naturally to the role of management in this regard. Management attitudes towards the control programme will strongly influence the level of exposure below the control limits that will be considered practically achievable. More generally, these attitudes will undoubtedly have a considerable influence on the vigour with which management pursues health and safety programmes through the IRS and its degree of co-operation with the worker members of joint health and safety committees.

We believe that management attitudes towards worker health will be significantly conditioned by the extent to which supervisory personnel understand the risks that can be presented to workers by various situations. This calls for training designed to impart the requisite knowledge. It also calls for a setting in which supervisory personnel with the requisite training will be on hand whenever plant operation or maintenance entails worker exposure to asbestos. The Luce and Swimmer study uncovered allegations that some of the dustiest operations occurred on the night shift. In this light, we recommend that:

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<sup>57</sup>Canada/Ontario, *The Report of the Joint Federal-Provincial Inquiry Commission into Safety in Mines and Mining Plants in Ontario: Towards Safe Production* (Burkett Report), Kevin M. Burkett, Chairman, vol. 1 (Toronto: April 1981), p. 79.

- 8.8 *The Regulation Respecting Asbestos should be amended so as to require that every employer with a control programme must select persons who have supervisory positions for training in the nature of the hazards posed by asbestos, and in identifying and dealing with the specific workplace situations that may be most hazardous. The number of persons trained should be sufficient to ensure that one such person will be on duty in the plant at all times when its operation or maintenance entails worker exposure to asbestos.*

## D.5 The IRS and the Role of Ministry Inspectors

The testimony of past and current officials of the Ministry of Labour underlines the Ministry's support of the IRS. Inspection routines, accident and complaint investigations, responses to "right to refuse" situations, and routine monitoring activities have in principle been conditioned by the need to support and encourage the IRS. Indeed, labour representatives argue that the Ministry has gone too far, replacing immediate action with exhortations of support for joint committee action. We shall address the Ministry's enforcement role later in this chapter; for the moment, we take the submission of labour representatives as further evidence of the Ministry's commitment, through its inspectorate, to the IRS.

The Ministry has chosen to organize its inspectorate along geographical lines rather than specializing by industry or type of hazard. What speaks in favour of this mode of organization is that the front-line inspectorate gives the Ministry a comprehensive window on all aspects of health and safety in the workplace and an opportunity to monitor and encourage the development of the IRS in all its several dimensions. But this mode of organization also means that the front-line inspectors will of necessity be generalists. There is an uncertain demarcation line beyond which the Ministry's expectations of its inspectors may be super-human. This led Professor G. Bruce Doern, Professor Michael Prince, and Mr. Garth McNaughton, in their study for this Commission, to suggest that the Occupational Health Branch might assume the front-line inspectional role for matters of occupational health.<sup>58</sup> As we shall explain below, we ourselves conclude that there is a need for a specialized inspection unit where designated substances are present in the workplace. But such a unit should not operate in lieu of the Ministry's generalist inspectors. The comprehensive window which these inspectors give to the Ministry on each workplace should not be discarded. In reaching this conclusion, we draw in part on a review, conducted at our request by our staff, of the Ministry files for the specific brake plants whose workers were surveyed by Luce and Swimmer. In that these files

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<sup>58</sup>G. Bruce Doern, Michael Prince, and Garth McNaughton, *Living with Contradictions: Health and Safety Regulation and Implementation in Ontario*, Royal Commission on Asbestos Study Series, no. 5 (Toronto: Royal Commission on Asbestos, 1982), p. 5.14.

revealed a gratifying degree of inspector awareness of the problems independently identified by Luce and Swimmer, the value of the Ministry's comprehensive window is evident.

Of course, there is a need to ensure that generalist inspectors have a degree of training in matters of occupational health. If only by force of history, experienced front-line inspectors have been better equipped to deal with accident prevention than disease prevention. They must be sensitized to health hazards, and they must know what sources of expertise in the Occupational Health Branch are on tap to be called in. They require a basic understanding of control methods such as ventilation, a general grasp of the requirements of designated substances regulations — especially the ALARA principle — and an understanding of the principal elements of designated substance control programmes.

According to Ministry testimony before this Commission, no more than half of the current front-line inspectors have undergone such basic occupational health training.<sup>59</sup> We have not reviewed the adequacy of the content of this training. We urge the Ministry to do so, particularly with an eye on whether the health training of inspectors might be integrated with available joint labour-management training programmes. This would be much in line with the Ministry's policy of supporting the IRS. The Ministry should seek as expeditiously as possible to enhance the proportion of its inspectorate that has received health training. In the meantime, the Ministry should make every effort to ensure that the inspectors assigned to visit plants where designated substances are present are individuals who have received basic health training. The present asbestos-using industry consists of a small number of firms that are primary asbestos users — according to Chapter 6 of this Report, no more than a dozen. In addition to these, a few dozen more use non-trivial amounts of asbestos and are therefore covered by the Regulation Respecting Asbestos. If this pattern is typical of most of the industries in which designated substances are used, it may well be feasible to ensure that the inspectors assigned are those who have already received health training. In line with these considerations, we recommend that:

- 8.9** *The Ministry of Labour should review the content of the basic occupational health training it offers to Industrial Health and Safety Branch inspectors with a view to its adequacy and to whether it might be integrated with available joint labour-management health training programmes, and the Ministry should seek as expeditiously as possible to enhance the proportion of its inspectorate that has received occupational health training. As an interim measure, the Ministry should make every effort to ensure that the inspectors assigned to*

<sup>59</sup>RCA Transcript, Evidence of Mr. Walter Melinyshyn, 22 June 1982, Volume no. 43(A), p. 31.

*plants where designated substances are present are individuals who have received basic occupational health training.*

## **E. Beyond the Internal Responsibility System**

### **E.1 A Designated Substances Enforcement Unit**

The IRS is at once the desirable and the practical approach to occupational health and safety. This is because the central goal of accident and disease prevention hinges on the concerted efforts of all who are associated with the workplace, and because no government agency could conceivably ensure that health and safety are fully policed. If there are problems with the IRS, this is due in part to its recency. It evidently stands in need of improvement. Given what we view as the greater complexity of disease prevention, we would expect the IRS to approach its full potential in occupational safety before it becomes as effective in occupational health. The recommendations we have made so far are intended to lend direct support to the favourable development of the IRS in matters of health; further recommendations made in Chapter 14 are likewise intended to lend direct support. We believe, however, that *indirectly*, the development of the IRS in the domain of occupational health can be abetted through a measured dose of firm policing. The litany of complaints we have heard about the problem of dealing with designated substances is such as to cause us grave concern if only because it bespeaks a lack of worker confidence in the occupational health regime. There is a perceived lack of response by the Ministry of Labour to complaints from joint health and safety committees and a perceived lack of prosecution in cases where orders have not been complied with within the specified time. While these problems may occur in a variety of health and safety areas, they are of special concern with respect to designated substances because it may be more difficult for joint health and safety committees to maintain pressure over a period of time where the harmful effect is not obvious and lies far in the future. We believe that the Ministry should effectively respond to this problem by creating a Designated Substances Enforcement Unit (DSEU).

The DSEU should be constituted so as to command the full range of multidisciplinary technical expertise necessary to enforce designated substances regulations. Its focus would be on health; its mandate, to enforce the regulations. The DSEU should be headed by a Ministry official with the rank of Branch Director. This official, among his other qualifications, should have thorough knowledge of the powers of the Ministry of Labour and of investigative procedures, including circumstances where search warrants should be sought and may be issued. This official would have the authority to launch special, unannounced inspections of plants in which designated substances are in use and to commandeer a team of appropriate Ministry experts assembled separately for each plant visit. The composition

of the team would depend upon the designated substance in question and the types of expertise necessary to examine compliance with the regulations at the particular workplace. Thus, other than for its Director, the DSEU would not consist of additional full-time staff of the Ministry, but would rather be a term applied to regular staff assembled on particular occasions for a particular purpose. A visit from the DSEU would differ from an ordinary visit by a Ministry of Labour inspector in several respects. First, each visit would be made by a team consisting of a number of experts, rather than a single inspector. The team would presumably include one or more experts in control methods for the designated substance, which in the case of asbestos would require an individual expert in ventilation and in the use of respirators; an expert in measuring concentrations of the designated substance, who could both perform some measurements and carefully review the measurement records kept in the workplace to check their completeness and accuracy; and someone who would be competent to determine whether all of the regulations applying to designated substances were being fully complied with in the workplace. Where the size of the workplace was substantial, several experts of each type might be required in order carefully to examine the plant on a single visit. The DSEU might visit outside regular business hours, where a plant normally operated outside those hours.

In deciding whether to launch a visit, the Director of the DSEU could appropriately take account of the advice of inspectors, workers, unions, police, or any member of the public who suspects that regulations are not being met. He could also choose randomly from the list of workplaces where designated substances are used. In the case of asbestos, there are about a dozen major users in Ontario, and a few dozen more firms that from time to time use small quantities of asbestos. The Director of the DSEU would choose a strategy for visiting these plants in a way such as to maximize the likelihood of identifying and dealing with significant problems. The visits of the DSEU would be above and beyond the normal visits by Ministry inspectors and should have no impact on such visits, unless the DSEU recommended that a follow-up visit by an inspector be performed. Following an inspection, the DSEU would file a report with the Ministry, the employer, and the worker representatives on the health and safety committee, which included general findings at the workplace, compliance orders with specific expiry dates attached, stop work orders, if necessary, and recommendations for prosecution where significant violations were detected. The DSEU would pay special attention to compliance orders from field inspectors that had expired but were not complied with, and to long-standing complaints by the joint health and safety committee. Its attitude should reflect the importance of achieving compliance with control limits and the ALARA principle as a condition for using a designated substance in the workplace.

The philosophy of the DSEU would evidently differ from the general compliance philosophy of the Ministry of Labour. The DSEU is designed to

provide a tough enforcement capability that is not generally present in the Ministry's reliance on the Internal Responsibility System. The DSEU might be less flexible and less generous in dealing with compliance problems than would be an inspector who is inevitably in a long-term relationship with the parties and a consultant-promoter of the IRS. Of course, the DSEU cannot be so rigid and uncompromising that it completely undermines the Ministry's attempts to develop a co-operative attitude between the employer and the Ministry and between the employer and the employee. It is not our intention through implementation of the DSEU to undermine or weaken the IRS. Rather, we intend the DSEU to lend the IRS indirect support.

Inspection by the DSEU could be of assistance to employers who may be complying with standards but may be unable to convince employees of their performance. It should alter the perception of labour groups and workers who feel that current inspections lack substance and that the Ministry is too lenient. It should help the Ministry to ensure that its statutes are enforced without turning its entire Division into a police force. The multidisciplinary DSEU team will likely find areas for improvement in the workplace even where the regulations are being met. The report of their findings will provide opportunity for the joint committee to focus on specifics.

In several respects the DSEU as described addresses the problems of enforcement that have been brought to our attention. First, the multidisciplinary nature of each inspection team recognizes the range of specialties involved in designated substance control while simultaneously allowing for, and indeed abetting, the continued and desirable role of generalist inspectors deployed on a geographical basis. Second, the DSEU recognizes that the need for a positive Ministry enforcement role may be greater in matters of health than in those of safety. Workers and first-line supervisors may be the most important parties in safety; in health, the onus shifts to the engineer, technician, and scientist. Third, the submissions from labour and the study by Luce and Swimmer have indicated that there is a good deal of suspicion in the workplace that conditions respecting occupational health are not as they should be. The routine inspection from the Ministry is sometimes not reassuring and indeed may not even be noticed. A blitz from a well-equipped Ministry team would be far more impressive and could improve worker perception. Fourth, follow-up to the kinds of allegations brought to the attention of this Commission involves police work as much as inspection. Rumours that a plant operates its dirty machines only in the middle of the night or that a plant with non-English speaking immigrant workers is ignoring the law may require the kind of follow-up that is more typical of police work than routine field inspection. In a different but related context, the Ontario Ministry of the Environment found this to be the case and has established a special police enforcement

unit.<sup>60</sup> Finally, we have become aware that a problem with the Ministry of Labour lies in appearance: it just does not look like a tough enforcement organization. Appearances are important, not only in satisfying workers but also in convincing employers and managers that control actions are essential. Accordingly, we recommend that:

*8.10 The Ministry of Labour should create a Designated Substances Enforcement Unit (DSEU), headed by an official with the rank of Branch Director. This official would have the authority to launch special, unannounced inspection visits of plants in which designated substances are in use and to commandeer a multidisciplinary team of appropriate Ministry experts assembled separately for each inspection visit. Each DSEU team should have all the powers of a Ministry of Labour inspector.*

## E.2 Medical Surveillance: The Examining Physician

The Regulation Respecting Asbestos requires in section 13(1) that the worker, at the expense of the employer, shall undergo medical examination and clinical tests. Sections 14, 15, and 16, as well as the Code for Medical Surveillance, cover the information to be gathered under the medical surveillance programme and the maintenance of the records kept therefor. It is not clear from the Regulation, however, who selects the physician to conduct the examination. Labour has indicated its preference that the worker be entitled to choose the examining physician. One document filed with the Commission, a memorandum from the Director of the Legal Services Branch of the Ministry of Labour concerning selection of the physician for conducting examinations regarding lead, stated that under the Regulation the employer would select the physician to conduct this examination.<sup>61</sup> The Ministry of Labour is developing a general guide to the designated substances regulations which will address the issue. We have been informed that the Ministry believes that the physician should be selected in consultation with the joint health and safety committee. However, the Ministry recognizes that there is no requirement in law for a single physician to con-

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<sup>60</sup>The Ministry of the Environment, given problems of non-compliance with regulations, created a set of special enforcement units (SIUs) to deal with these problems. Announced by the Minister in October 1980, the SIUs consist of one or two staff at each regional office who have been trained in investigative methods at police college. The SIUs are apparently highly effective in gathering the background information necessary to support the successful prosecution of a serious offender.

<sup>61</sup>RCA Exhibit II-60(c), in RCA Transcript, Evidence of Mr. Walter Melinyshyn, 22 June 1982, Volume no. 43(A): Ontario, Ministry of Labour, Memorandum from Mr. Paul Hess, Director, Legal Services Branch to Mr. Alan Heath, Director, Standards and Programs Branch, 22 April 1982.

duct the examinations in the plant, and that individual workers can choose their own family doctors.<sup>62</sup>

We received a number of representations on the issue of who is an appropriate examining physician. Workers are frequently mistrustful of "company doctors," believing them not to be completely independent in judgements made about worker health. On the side of company physicians, concerns have been expressed to this Commission that physicians selected by individual workers might not necessarily have the competence necessary for evaluating specific work-related diseases which are often not common in the general population. It has become apparent to us that the degree of controversy over who should be the examining physician has been heightened by the role which the Regulation assigns to this individual. In this regard, section 16(1) of the Regulation gives the examining physician the authority to declare whether the employee is "... fit ... fit with limitations or unfit, to work in an asbestos exposure." In testimony before us and in subsequent correspondence with this Commission, Dr. Jerome J. Vingilis, formerly of the Ministry of Labour, expressed his concern that certain company physicians might abuse the authority to declare a worker unfit.<sup>63</sup>

Later in this Report, for reasons stated in Chapter 14, we recommend that the examining physician should cease to have the authority to declare workers fit or unfit to work in an asbestos exposure. This removes one source of the controversy over who the examining physician should be. In that the controversy remains, we express the strong view that, ideally, the examining physician should be chosen jointly by labour and management. More generally, we believe that the most important factor in physician selection should be the competence of the physician who is to examine the worker.

We consider that the most likely and convenient source of expertise is to be found among company doctors. Such physicians, by the inherent nature of the positions they hold, are at once repositories of experience in occupational medicine and, in the specific domain of asbestos, bound to become familiar with the provisions of the Code for Medical Surveillance. The interests of employers, employees, and company physicians themselves are well served only where an atmosphere of trust prevails. Just as the quality of the patient-physician relationship can vary as between different individuals and their personal doctors, so too may the degree of trust that

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<sup>62</sup>Letter from Mr. Arthur L. Gladstone, Senior Policy Advisor, Occupational Health and Safety Division, Ontario Ministry of Labour to the Royal Commission on Asbestos, 22 July 1983.

<sup>63</sup>Letter from Dr. Jerome J. Vingilis to Mr. Thomas Lederer, counsel representing the Government of Ontario with respect to the Royal Commission on Asbestos, 4 August 1982.

prevails with respect to the medical services provided in different workplaces. It will always be incumbent upon management and labour to strive to create an atmosphere of trust in the examining physician; agreement over the identity of this person should therefore always be sought. In many workplaces, this matter can be productively worked out through labour-management deliberations. In others, for any of a number of unfortunate reasons, the matter may fester in controversy.

Such instances of controversy, whatever their source, cannot be regulated out of existence. Given this stark reality, our approach is to emphasize the importance of stressing the right of the individual employee to seek the appropriate medical examination from a physician of his own choosing. With respect to designated substance workplaces, what is necessary, in our view, is that such an examining physician should know the content of the appropriate Code for Medical Surveillance.

We conclude that the Regulation Respecting Asbestos should explicitly reflect the above considerations. This can be done by stipulating that the examining physician would be designated by the employer, save that any individual employee would have the right to be examined, at the employer's expense, by a physician of his own choosing. Such a physician, however, would have to certify that the employee's examination was conducted in accordance with the Code for Medical Surveillance. We appreciate that such explicit regulatory language could become a source of employer inconvenience in workplaces where a substantial number of workers choose to exercise their right to examination by a correspondingly large number of different physicians. But this possibility is only likely in those workplaces where an atmosphere of trust is absent. We view it as a positive incentive to management to secure the agreement of labour to the employer's choice of examining physician. We therefore recommend that:

*8.11 The Regulation Respecting Asbestos should be amended to clarify that the examining physician under sections 13 to 16 shall be the physician designated by the employer, but that any employee shall have the right to be examined, at the expense of the employer, by a physician selected by the employee, provided this physician certifies to the employer that he has conducted the examination in accordance with the Code for Medical Surveillance of Asbestos Exposed Workers.*

### **E.3 Medical Surveillance: Maintaining Records**

The Regulation Respecting Asbestos requires the physician who examines a worker to maintain medical and exposure records in a secure place.<sup>64</sup> Where the physician is no longer able or willing to keep the records,

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<sup>64</sup>Regulation Respecting Asbestos, s. 15(1).

they are to be forwarded to the Chief Physician of the Occupational Health Medical Service in the Ministry of Labour, or his designate.<sup>65</sup> The maintenance of these records is important for continuing studies of the health effects of designated substances, for the verification of claims and formulation of policies by the Workers' Compensation Board, perhaps to determine compliance with the control limits, and in some cases to determine whether a worker has been excessively exposed to a substance and should be treated or removed from that exposure.

The Regulation does not, however, indicate where geographically these records must be maintained. It appears quite possible under the Regulation to maintain these records in locations outside the province of Ontario. If this happens, then access to these records by the worker, the Ministry of Labour, or others who require them for one of the reasons stated above may be difficult. It can be virtually impossible to compel someone to produce records that are not physically located in the province.

We have become aware of instances where accessibility to records for research purposes has been problematic. In one case, when a medical researcher from the Ministry of Labour undertook an epidemiological study of the health experiences of workers at the Johns-Manville plant in Scarborough, he experienced considerable difficulty in acquiring all the necessary medical records.<sup>66</sup> When Bendix Automotive of Canada Limited closed its Windsor, Ontario plant, concern was expressed to us that medical records might be transferred to U.S. headquarters.<sup>67</sup> In fact, the Ontario Ministry of Labour has gained access to these records and is currently conducting epidemiological research with them. Nevertheless, the point remains that problems of accessibility can materialize in cases where medical records are transferred out of jurisdiction.

While companies such as Johns-Manville or Bendix have an obligation to ensure that the records of their employees are not released injudiciously,<sup>68</sup> workers and the scientific community have a right to some guarantee that there are records in Ontario with respect to which they can apply for

<sup>65</sup>Ibid., s. 15(2).

<sup>66</sup>See discussions of this issue in RCA Transcript, Evidence of Mr. Jack P. Cashman, 23 June 1982, Volume no. 44, pp. 107-114; RCA Transcript, Evidence of Dr. Paul Kotin, 29 June 1982, Volume no. 46, pp. 54-60, 118-137; and RCA Exhibit II-75, in RCA Transcript, Evidence of Dr. Paul Kotin, 29 June 1982, Volume no. 46: Correspondence between Johns-Manville and Dr. Murray M. Finkelstein, Ontario Ministry of Labour.

<sup>67</sup>Letter from Professor Frank C. Innes, Department of Geography, University of Windsor to the Royal Commission on Asbestos, 23 June 1980; RCA Transcript, Submission by Professor Frank C. Innes, 27 March 1981, Volume no. 6, p. 43; and International Union, United Automobile, Aerospace and Agricultural Implement Workers of America (UAW), Written submission to the Royal Commission on Asbestos, #34 [January 1981], p. 16.

<sup>68</sup>See a discussion of this issue in RCA Transcript, Evidence of Dr. Paul Kotin, 29 June 1982, Volume no. 46, pp. 56-60.

access for legitimate purposes. In this regard, section 15(1) of the Regulation is deficient because it does not stipulate that the records to which it refers must be kept in Ontario.

Beyond the fact that the Regulation fails to stipulate that records be kept in Ontario, we find more generally that the Regulation assigns too great a role to the examining physician in record maintenance. Short of the point at which, pursuant to section 15(2) of the Regulation, examining physicians who are no longer willing to keep records fulfill their obligation to forward them to the Chief Physician of the Occupational Health Medical Service of the Ministry, records will be in the keeping of physicians scattered throughout Ontario. This is a backward step from the practice whereby the chest X-rays of asbestos workers under surveillance by the Ministry's Chest Surveillance Programme were kept by the Ministry, with copies deposited in the Medical Services Division of the Workers' Compensation Board. As we point out in Chapters 13 and 14, these relatively complete records have never been systematically analyzed, but have proved useful to the Board, particularly in matters related to worker removal and rehabilitation. The record maintenance role now assigned to individual examining physicians will destroy the continuity of what has become a long and potentially valuable time series of records on workers who have been exposed to asbestos. Section 15(2) of the Regulation envisages that records can wind up being stored by the Chief Physician of the Ministry's Occupational Health Medical Service once examining physicians are no longer able or willing to keep them; we deem it highly desirable that copies of all records should be deposited with the Chief Physician at the time they are made, thereby simultaneously assuring that they are all available at one location and that this location is in Ontario.

This resolution poses an issue to which we are sensitive; the confidentiality of the medical records of the individual involved. Its complexities are so far-reaching that it was the subject of Mr. Justice Horace Krever's Commission of Inquiry into the Confidentiality of Health Information.<sup>69</sup> The report by that Commission specifically addressed matters of confidentiality arising from the *Occupational Health and Safety Act* and contained no fewer than seventeen recommendations on this subject. These recommendations seek to ensure stringent control of the medical records in the safekeeping of the Ministry so as to safeguard the privacy of the individual. As of the time of writing, these recommendations still awaited the response of the Government of Ontario.

We endorse the depositing of medical records with the Chief Physician of the Ministry of Labour on the explicit condition that the recommen-

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<sup>69</sup>Ontario, *Report of the Commission of Inquiry into the Confidentiality of Health Information* (Krever Report), The Honourable Mr. Justice Horace Krever, Commissioner, 3 vols. (Toronto: Queen's Printer for Ontario, 1981), and especially chap. 33 therein.

dations of the Commission of Inquiry into the Confidentiality of Health Information will be implemented. We therefore recommend that:

- 8.12 *The Regulation Respecting Asbestos should be amended so as to substitute for the role of examining physicians in maintaining the records, referred to in section 15(1), an obligation on examining physicians to forward the records or copies thereof to the Chief Physician, Occupational Health Medical Service of the Ministry of Labour. The system of control pursuant to which the Ministry maintains these records should be that prescribed by the Ontario Commission of Inquiry into the Confidentiality of Health Information.*

#### **E.4 Medical Surveillance: A Concluding Note**

We have restricted ourselves, in the matter of medical surveillance for current asbestos workers, to addressing the choice of the examining physician and the maintenance of records. These are immediate and practical matters that lend themselves to formal recommendations at this time. There is a much larger question of which we are conscious, namely, the purposes that medical surveillance is intended to serve. For reasons which we give in Chapter 14, the kind of medical surveillance envisaged by the Regulation Respecting Asbestos is far more relevant to workers whose employment in the asbestos industry dates back a decade or more, when exposure levels were such as to create a significant risk of asbestosis, than it is to workers who have recently become employed. It may well be that some of the procedures prescribed by the Code for Medical Surveillance which accompanies the Regulation are excessive when applied to recently employed workers. Having raised this issue, we have concluded that the time to resolve it has not yet come. Low exposure is relatively recent, and a uniform procedure for the surveillance of all asbestos workers serves, for the time being, as an additional check on the extent to which the low exposures mandated by the Regulation Respecting Asbestos are in fact enforced.



## **Part IV**

# **Asbestos in Buildings**



## Chapter 9 Problems of Asbestos in Buildings

### A. Introduction

Part III of this Report dealt with the exposure of workers to asbestos in fixed workplaces. We now turn to the second major problem area of asbestos exposure in Ontario: the exposure of occupants and workers to asbestos fibres in buildings. In a study prepared for this Commission, Professor G. Bruce Doern reported that it was the death of a school maintenance worker, Mr. Clifton Grant, a carpenter, as a result of an asbestos-related disease, that led in part to the public pressure which resulted both in the establishment of this Commission and in the establishment of the provincial programme for controlling asbestos exposure in schools.<sup>1</sup>

In this chapter we will first describe the way in which asbestos was used in buildings in the past and the exposure of workers who installed that asbestos. We will then consider evidence on levels of exposure of building occupants and workers to asbestos that is already present in buildings. The particular problems involved in trying to measure asbestos hazards in buildings will be discussed. The last three sections of this chapter will evaluate the health risks faced by building occupants and the actions necessary to protect these occupants from significant risks.

This chapter will show that workers who installed or removed sprayed or pipe and boiler insulation containing asbestos without taking precautions for their own safety were exposed to high levels of asbestos fibres in the air.

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<sup>1</sup>G. Bruce Doern, *The Politics of Risk: The Identification of Toxic and Other Hazardous Substances in Canada*, Royal Commission on Asbestos Study Series, no. 4 (Toronto: Royal Commission on Asbestos, 1982), pp. 2.11-2.15.

Exposures of 5 to 10 fibres per cubic centimetre (f/cc) were common, and some workers were exposed to concentrations as high as 100 f/cc or more. One study has estimated that the insulation workers as a group were exposed on average over their careers to fibre levels ranging from 10 to 15 f/cc. As Chapter 5 shows, studies of these insulation workers in North America have revealed a tragic toll of disease and death resulting from this exposure.

In dramatic contrast, the exposure of building occupants to asbestos fibres during normal building use will be shown to be insignificant, whether as compared to the exposure of insulation workers in the past or as compared to the much lower exposures permitted by the recently adopted Ontario workplace control limits of 1.0, 0.5, and 0.2 f/cc for chrysotile, amosite, and crocidolite asbestos. Studies of asbestos concentrations in building air have shown that many buildings containing asbestos insulation do not exhibit fibre levels exceeding those in the outdoor air or in buildings not insulated with asbestos. Even when a building exhibits elevated asbestos fibre levels, these are still very low compared to current workplace control limits and are orders of magnitude below the level to which workers were exposed in the past. A typical building containing asbestos insulation will expose occupants to less than 0.001 f/cc of asbestos, or 1/1,000 of the current chrysotile control limit. Only a small fraction of occupant exposures in all buildings containing asbestos insulation would be as great as 0.01 f/cc of asbestos.

We will conclude that it is rarely necessary to take corrective action in buildings containing asbestos insulation in order to protect the general occupants of those buildings. On the other hand, construction, demolition, renovation, maintenance, and custodial workers in asbestos-containing buildings may be exposed to significant asbestos fibre levels and may, during their work, cause elevated fibre levels for nearby occupants. We will devote Chapter 10 to the problems of protecting these workers and of protecting occupants from possible fibre release as a result of building work. This, and not the protection of building occupants in the absence of such work, is the real challenge that asbestos insulation in buildings presents.

In this chapter we will use the word “building” in its usual sense, meaning an office, apartment, factory, warehouse, or other enclosed fixed structure frequented by people. We will see in Chapter 10 that while the vast majority of asbestos problems occur in such buildings, regulations protecting construction, demolition, renovation, maintenance, and custodial workers must extend to all construction projects including work on other structures such as subway tunnels, above-ground pipelines, and transformer vaults. Thus, in Chapter 10 we expand the definition of “building” to include any structure, enclosed or not, above ground or below, other than mines.

## B. Exposure During Past Construction

A large number of products used in the construction industry contain, or have in the past contained, asbestos. These products may be divided into three categories. The first consists of asbestos-containing products used or applied in a liquid state. The release of asbestos fibres at any time from such products is unlikely, because the fibres are combined with and held down by a liquid. Examples include asbestos-containing paints and asbestos-asphalt roofing compounds. Once asbestos fibres have become impregnated with liquids such as paint or asphalt, it is very unlikely that they can become airborne again.

The second category of asbestos products is hard products, in which the asbestos fibres are firmly embedded in a solid material and are unlikely to be released during normal use. Examples include floor tiles, asbestos-cement products, hard ceiling tiles, drywall taping and joining compounds, and impregnated paper and textile products. Fibres could only be released from these products during sanding, grinding, cutting, or other work on the product during installation, renovation, or removal. Asbestos-containing floor tiles and asbestos-cement products are still used in new construction, and the exposure of workers who operate on these materials will be described in Chapter 10, Section D.2. Recommendation 10.17 prescribes safe work practices. Hard ceiling tiles and drywall taping and joining compounds might be encountered by maintenance, renovation, or demolition workers and are also encompassed by Recommendation 10.17. Asbestos-impregnated paper products were for the most part used for pipe and boiler insulation: see Section B.2 of this chapter and Chapter 10, Recommendation 10.16. Asbestos-impregnated textile products are discussed in Chapter 11, Section A. Safe work practices are dealt with in Chapter 10, Recommendation 10.17.

Finally, there are the friable, or crumbly, asbestos-containing materials such as asbestos-containing sprayed insulation and asbestos-containing pipe and boiler insulation. Friable material, defined in the United States Code of Federal Regulations, as material “. . . that can be crumbled, pulverized, or reduced to powder, when dry, by hand pressure,” ranges from material which falls apart at the slightest touch to products with a relatively hard surface.<sup>2</sup> These materials have in the past caused substantial exposure of workers to asbestos fibres during installation and may continue to cause substantial exposure when maintenance or renovation work is performed that will disturb the material, or when the material is removed, enclosed, or encapsulated. We will first discuss sprayed insulation and then pipe and boiler insulation.

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<sup>2</sup>U.S., Environmental Protection Agency, *National Emission Standard for Asbestos*, 40 CFR 61.21(k).

## B.1 Sprayed Asbestos-Containing Insulating Material

The spray application of asbestos fibre insulation was introduced in 1932 in Great Britain and within a few years was adopted in the United States and then in Canada. This process was originally used for thermal insulation, decorative purposes, and acoustical control, but after 1950 it was used primarily as a fireproofing to protect structural steel from heat in case of fire. The amount of asbestos-containing sprayed material installed before 1950 is a small fraction of the amount installed after 1950. Reitze et al. reported that the first use of sprayed mineral fibres for fireproofing in a large multi-storey building in the United States was in 1958.<sup>3</sup> Use of sprayed asbestos-containing fireproofing grew through the 1960s and far exceeded the use of asbestos-containing sprayed material for thermal, decorative, and acoustical purposes. In 1973, the spray application of asbestos material was banned in the United States by the U.S. Environmental Protection Agency (EPA). Canadian insulation manufacturers voluntarily stopped using sprayed asbestos insulation in 1973, responding in part to Regulation 419/73, section 33, under the Ontario *Construction Safety Act*, which required costly safety precautions when spraying asbestos insulation.<sup>4</sup> In 1978, the United Kingdom Advisory Committee on Asbestos recommended that the spraying of asbestos-containing coatings should be prohibited; and in 1981, the Health and Safety Commission issued a *Consultative Document: Asbestos Insulation and Coating — Draft Regulations*, which proposed prohibiting the spraying of any product containing more than one asbestos fibre per milligram of product. This document stated that in fact, by 1979, the process of spraying asbestos-containing insulation in the United Kingdom had been almost entirely discontinued.<sup>5</sup>

Sprayed asbestos-containing fireproofing was applied by either a wet or a dry process. In the wet process, chrysotile or amosite asbestos (at 5 to 30% by weight of the total formula) and some other fibres were mixed with a binder such as cement or gypsum and water and then sprayed onto the building surface. The resulting product is relatively hard and dense. The dry process was more common in Ontario than the wet process and tended to use either chrysotile, usually at 5 to 70% by weight, or amosite, usually at 50 to 90% by weight, with some other fibres and binder. In North America,

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<sup>3</sup>William Reitze et al., "Application of Sprayed Inorganic Fiber Containing Asbestos: Occupational Health Hazards," *American Industrial Hygiene Association Journal* 33:3 (March 1972): 178-191.

<sup>4</sup>Ontario, Ministry of Labour, Written submission to the Royal Commission on Asbestos, #43, February 1981, p. 16.

<sup>5</sup>U.K., Advisory Committee on Asbestos, *Asbestos — Work on Thermal and Acoustic Insulation and Sprayed Coatings* (London: Her Majesty's Stationery Office, 1978), paragraph 21, p. 13; and U.K., Health and Safety Commission, *Consultative Document: Asbestos Insulation and Coating — Draft Regulations* (London: Her Majesty's Stationery Office, 1981), p. 1.

crocidolite was less commonly used. It was substituted, at 50 to 90% by weight, in a small number of dry-applied applications. The dry mixture was blown through a nozzle and wetted by a water spray as it left the nozzle. This dry process resulted in a material with much lower density in place and with greater thickness than the wet process material, thus making fibre release more likely. The three types of asbestos were rarely, if ever, mixed in asbestos-containing sprayed insulation, wet- or dry-applied.<sup>6</sup>

It is generally agreed that disturbing sprayed asbestos-containing insulation, whether in the process of installing it or when it is in place, generates greater airborne fibre concentrations if the asbestos is crocidolite or amosite than if it is chrysotile.<sup>7</sup> This is due to differences among the physical characteristics of the sprayed product and perhaps to differences among the fibre types themselves. The presence of crocidolite or amosite thus presents a greater health risk, quite apart from any difference in the toxicity of a single fibre of different types of asbestos.

In Ontario, most sprayed insulation was installed by fireproofing contractors, many of whom belonged to the Master Insulators Association. The work itself was done by insulation workers who were members of Local 95 of the International Association of Heat and Frost Insulators and Asbestos Workers. Membership in this union numbers about 700 in Ontario. Some of the high exposure experiences of these workers have been described in Local 95's written submission to the Commission.<sup>8</sup>

Scientific studies have confirmed that spraying asbestos-containing materials generated considerable levels of fibre exposure for the workers. Reitze et al. reported that spraying dry-process asbestos material onto a powerhouse turbine yielded fibre concentrations for the worker operating the spray nozzle ranging from 32 to 100 f/cc, while the worker charging the hopper experienced exposures of 5 to 22 f/cc.<sup>9</sup> The same study examined the spraying of fireproofing on a multi-storey building and found fibre counts for the worker at the nozzle of 20 to 100 f/cc and fibre counts at distances of 10 to 75 feet from the nozzle ranging from 10 to 71 f/cc during

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<sup>6</sup>Donald J. Pinchin, *Asbestos in Buildings*, Royal Commission on Asbestos Study Series, no. 8 (Toronto: Royal Commission on Asbestos, 1982), p. 1.5; and Personal communication between Dr. Donald J. Pinchin, D.J. Pinchin Technical Consulting Ltd. and Royal Commission on Asbestos Staff, 4 February 1983.

<sup>7</sup>Ontario, Royal Commission on Asbestos, Transcript of Public Hearings [hereafter RCA Transcript], Evidence of Dr. John M.G. Davis, 15 January 1982, Volume no. 34, p. 28; and Personal communication between Dr. Donald J. Pinchin and Royal Commission on Asbestos Staff, 4 February 1983.

<sup>8</sup>International Association of Heat and Frost Insulators and Asbestos Workers, Local 95, Written submission to the Royal Commission on Asbestos, #88, 10 June 1982.

<sup>9</sup>Reitze et al., "Application of Sprayed Inorganic Fiber Containing Asbestos: Occupational Health Hazards," p. 181.

the spraying operation.<sup>10</sup> Thirty minutes after spraying had stopped, fibre counts ranged from 1 to 4 f/cc, and 60 minutes after the end of spraying, all counts were below 1 f/cc, probably because the dust was blown away through the open sides of the uncompleted building.

Skidmore and Jones reported that the nozzle worker spraying a wet process asbestos fireproofing was exposed to between 1 and 8 f/cc when care was taken to minimize dust release.<sup>11</sup> Barnes reported that spraying dry-process chrysotile generated fibre levels of 80 f/cc for the nozzle worker and 5 to 15 f/cc at floor levels located below the spraying operation.<sup>12</sup> It thus appears that insulation applications may have exposed insulation workers to fibre levels of between 5 and 100 f/cc. Other workers on the job site have experienced exposures in the range of 1 to 71 f/cc. The U.S. EPA has estimated that insulation workers encountered average exposure levels over their working lives of between 3 and 15 f/cc, with an average of 9 f/cc, while Nicholson estimated the average exposure at 10 to 15 f/cc.<sup>13</sup> In the Appendix to Chapter 7 of this Report, Daniels and Roberts assume an average exposure of 15 f/cc.

Where the asbestos was sprayed on an open building structure, the spray material could be carried into the outdoor environment. Selikoff, Nicholson, and Langer measured airborne asbestos concentrations in New York City at a variety of locations, including locations near construction sites where fireproofing was being sprayed. The asbestos concentrations ranged from an average of less than 10 nanograms per cubic metre (ng/m<sup>3</sup>) of air<sup>14</sup> in Queens and Staten Island to an average of 30 ng/m<sup>3</sup> of air in Manhattan.<sup>15</sup> Within one-quarter mile of a spray fireproofing site, the average asbestos concentration was 60 ng/m<sup>3</sup>, with a range up to 375 ng/m<sup>3</sup>. Up to one-half mile away, the average concentration was 25 ng/m<sup>3</sup>, with a range up to 54 ng/m<sup>3</sup>. The report concluded that “. . . at least in the areas sampled, there is a background of chrysotile contamination of the

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<sup>10</sup>Ibid., p. 182.

<sup>11</sup>J.W. Skidmore and J.S. Jones, “Monitoring an Asbestos Spray Process,” *Annals of Occupational Hygiene* 18:2 (September 1975): 154.

<sup>12</sup>R. Barnes, “Asbestos Spraying, An Occupational and Environmental Hazard,” *Medical Journal of Australia* 2:16 (16 October 1976): 600.

<sup>13</sup>U.S., Environmental Protection Agency, Office of Toxic Substances, *Support Document for Final Rule on Friable Asbestos-Containing Materials in School Buildings: Health Effects and Magnitude of Exposure* (Washington, D.C.: U.S. Environmental Protection Agency, January 1982), p. 90. See also, William J. Nicholson, *Dose-Response Relationships for Asbestos and Inorganic Fibers* (New York: Environmental Sciences Laboratory, Mount Sinai School of Medicine of the City University of New York, 15 February 1981), p. 26.

<sup>14</sup>The mass, or weight, of asbestos in the air may be expressed in terms of nanograms, or billionths of a gram, of asbestos per cubic metre of air. Mass measurements are not easily converted to fibre count equivalents. See Section D.3 of this chapter.

<sup>15</sup>Irving J. Selikoff, William J. Nicholson, and Arthur M. Langer, “Asbestos Air Pollution,” *Archives of Environmental Health* 25:1 (July 1972): 10–11.

ambient air and that this may be higher about construction sites in urban areas.’’<sup>16</sup>

The spraying of asbestos-containing insulation materials has been discontinued in Ontario under strict regulations for the spray process. We will show in Chapter 10 that the presence of asbestos-containing insulation in a building requires constant vigilance to protect building workers from excessive asbestos fibre levels. There we will recommend that asbestos insulation should be removed from any building before that building is demolished, imposing an additional cost on the owner. Sprayed insulation in buildings not only poses a risk for workers on the construction site, but poses possible risks for demolition, renovation, maintenance, and custodial workers in the building for its entire life. As well, we have seen that the process of installing sprayed asbestos-containing insulation tends to pollute the ambient air. Notwithstanding the regulations now in place, we believe that the application of sprayed insulation materials containing asbestos, wet or dry, should be prohibited.

This is contemplated in Ontario’s Proposed Regulation Respecting Asbestos on Construction Projects (PRRACP), in section 9(2): “No material containing asbestos shall be applied with a pressure spray system.”<sup>17</sup> The prohibition, however, should be framed in such a manner that it can be effectively enforced. As it stands, the wording of the proposed regulation could undermine its enforcement because it is impossible to analyze effectively to a zero concentration, and because many insulation materials contain trace amounts of asbestos as a material contaminant. In light of this, the U.S. EPA has prohibited the spraying of insulation containing more than 1% asbestos by weight.<sup>18</sup> We believe that 1% is the practical lower limit on the quantitative analysis of bulk material. Accordingly, we recommend that:

**9.1 *The Ministry of Labour should prohibit the spraying of friable material containing more than 1% asbestos on a dry-weight basis.***

Non-asbestos materials were used for fireproofing and insulation before 1950, and a variety of new non-asbestos fireproofing and insulation materials, including sprayed materials, are available at reasonable cost.

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<sup>16</sup>Ibid., p. 11.

<sup>17</sup>Ontario, Ministry of Labour, Occupational Health and Safety Division, “Proposed Regulation Respecting Asbestos on Construction Projects and Related Codes,” presented at a Public Meeting, 17 January 1983, Toronto, s. 9(2). (Mimeographed.) This “Proposed Regulation . . .” is a revision of the “Notice of Proposed Regulation: Designated Substance — Asbestos on Construction Projects,” *The Ontario Gazette*, vol. 115–33, Saturday, 14 August 1982, pp. 3194–3197.

<sup>18</sup>U.S., Environmental Protection Agency, *National Emission Standard for Asbestos*, 40 CFR 61.22(e).

Major substitutes for asbestos fibres include mineral wool and cellulose fibre. Cellulose fibre is frequently made from processed paper. These fibres are not highly durable in the lung and health hazards have not been found to result from the manufacture or use of this product.<sup>19</sup> In Chapter 6 we review the evidence on the health effects of breathing dust from mineral wool. Some evidence has suggested that mineral wool is no more hazardous than fibreglass.<sup>20</sup> Other studies have found that respiratory mortality is increased by exposure to mineral wool, but that the resulting standard mortality ratios (SMRs) are far lower than for asbestos.<sup>21</sup> We conclude, in Chapter 6, that the low historical disease record from exposure to mineral wool might reflect low historical worker exposures, and that processes that exposed workers to higher than previously experienced concentrations of smaller diameter fibres might result in serious disease. The absence of a completely clean bill of health for these materials suggests the wisdom of imposing standards that would avoid excessive worker exposure. We accordingly recommend that:

- 9.2 *The Ministry of Labour should assess, sponsoring studies where appropriate, the health risks associated with the fibres used as substitutes for asbestos in sprayed insulation, with a view to determining what regulations, if any, might be appropriate for the use of these substitutes.*

## B.2 Pipe and Boiler Insulation

Historically, a variety of products were used for insulating pipes and boilers. These included preformed thermal insulating sections or slabs, asbestos-cement compounds, corrugated asbestos paper, rope lagging, and asbestos tape.

Preformed thermal insulating sections or slabs were widely used for insulating or "lagging" pipes, boilers, and furnaces from the mid-1920s through 1972.<sup>22</sup> While the sprayed insulation discussed above needs no more structural integrity than that necessary to attach it to a surface, pre-

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<sup>19</sup>GCA Corporation, "Asbestos Substitute Performance Analysis," draft revised final report prepared by Nancy Krusell and David Cogley for U.S. Environmental Protection Agency, GCA-TR-81-32-G (Bedford, Mass.: GCA Corporation, February 1982), p. 305.

<sup>20</sup>Douglas P. Fowler, "Occupational Exposures to Mineral Wool," in *Proceedings of the National Workshop on Substitutes for Asbestos*, Arlington, Virginia: 14-16 July 1980, EPA-560/3-80-001 (Washington, D.C.: U.S. Environmental Protection Agency, November 1980), p. 400.

<sup>21</sup>Philip E. Enterline, Gary M. Marsh, and Nurtan A. Esmen, "Respiratory Disease Among Workers Exposed to Man-Made Mineral Fibers," *American Review of Respiratory Disease* 128:1 (July 1983): 1-7.

<sup>22</sup>Personal communication between Mr. Ian Dewar, Dewar Insulations Inc. and Royal Commission on Asbestos Staff, 8 March 1983.

formed thermal insulating sections maintain their shape during shipping and installation. At the same time, while preformed thermal insulating sections are structurally solid, they do not have the strength and durability of asbestos-cement products. A variety of fibre types and binding materials were used in manufacturing these sections, with asbestos usually representing 15% by weight of the product, and in any event not exceeding 80% by weight of the product. Magnesium carbonate and calcium silicate were the two most common binders.

Corrugated asbestos paper was sometimes made into preformed insulating sections for lower-temperature pipe insulation. This paper consists of almost pure asbestos.

While preformed sections were used on pipes and boilers, irregular fittings, such as elbows, Ts, and valves could not be covered by standardized preformed shapes. These fittings were, and to a small extent still are, covered by asbestos-cement compounds, rope lagging, or asbestos tape. These asbestos products were often used even on building projects where the insulating sections did not contain asbestos. Thus, while preformed insulating sections account for the greater quantity of asbestos in pipe and boiler lagging, the asbestos products used in irregular fittings may occur much more frequently and thus appear in buildings that use non-asbestos insulation for all other purposes.

Asbestos-cement compounds, sometimes referred to as asbestos-insulating cement, are powders with a high content of a commercial grade of asbestos fibres called "shorts" and with, in some cases, Portland cement used as a binder. They are mixed with water on the job site and applied in a dense mass by hand. Oddly, asbestos-insulating cement often contains no cement. The addition of water to the asbestos creates a material that retains its structural integrity when dried. Asbestos-insulating cement is quite different from what are known as asbestos-cement products, which always contain cement, are manufactured in a factory, are very hard, and are not used for insulating pipes and boilers. Frequently, asbestos-cement compounds, once installed, are less friable than insulating blocks or corrugated paper, because they are more dense. The three joint products — asbestos-cement compounds, rope lagging, and asbestos tape — are generally almost pure asbestos. However, once in place these products do not generate high dust levels.<sup>23</sup>

In his study for this Commission, Dr. Donald J. Pinchin noted that a higher proportion of Ontario buildings will contain asbestos-containing pipe coverings than sprayed asbestos-containing fireproofing.<sup>24</sup> The major

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<sup>23</sup>Ibid.

<sup>24</sup>Pinchin, *Asbestos in Buildings*, p. 3.18.

suppliers in Ontario of pipe and boiler insulation were Atlas Asbestos Company, Johns-Manville Canada, Holmes Insulations Ltd., and Philip Carey Company. Saheed et al. have reported that Atlas and Holmes used mainly amosite while Johns-Manville used crocidolite until 1960, followed by chrysotile from 1960 to 1973. By 1973, all four companies had stopped using asbestos in their pipe and boiler insulation products.<sup>25</sup>

Nicholson, reporting on Reitze's study of dust concentrations occurring in pipe and boiler insulation work, found that with the standard work practices of the 1960s, workers engaged in cutting and applying new insulating block or sections of pipe covering were exposed to 5.2 f/cc with good ventilation, and as much as 11.5 f/cc with poor ventilation. Workers engaged in mixing and applying asbestos-insulating cement and cloth covering to insulation material experienced 2.5 and 4.6 f/cc with good and poor ventilation respectively. Improved ventilation reduced these exposure levels by a factor of 2 or more.<sup>26</sup>

Once the insulation is installed, the heat from the pipe or boiler causes the insulation to become increasingly fragile, and thus more friable (or crumbly) over time. Accordingly, removal of old insulation could cause more dust than arose in the original installation. From the above we conclude that asbestos-containing pipe and boiler insulation presents a continuing hazard to building workers.

As with sprayed insulation, much of the asbestos-containing pipe and boiler insulation work in Ontario was performed by firms belonging to the Master Insulators Association, using workers from Local 95 of the International Association of Heat and Frost Insulators and Asbestos Workers.

The Ministry of Labour's Proposed Regulation Respecting Asbestos on Construction Projects does not appear to regulate the use of asbestos in pipe and boiler insulation. A draft regulation, "Asbestos Insulation and Coating," was prepared in the United Kingdom in 1981. This proposed regulation would prohibit the use of asbestos in pipe and boiler insulation.<sup>27</sup> Because of the continuing problem of worker exposure in buildings

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<sup>25</sup>W. Saheed et al., "Distribution and Concentrations of Asbestos Dust in Commonplace Construction Activities," a project conducted jointly by the University of Toronto, Department of Preventive Medicine and Biostatistics and the Construction Safety Association of Ontario, Research and Development Department, Toronto, 1978 (Mimeographed.); and Personal communication between Mr. Ian Dewar and Royal Commission on Asbestos Staff, 8 March 1983.

<sup>26</sup>William J. Nicholson, "Proposed Standard for Workers is Questioned," *Insulation Hygiene Progress Reports* 3:2 (Summer 1971): 3.

<sup>27</sup>U.K., Health and Safety Commission, *Consultative Document: Asbestos Insulation and Coating — Draft Regulations*, p. 3.

containing friable asbestos-containing pipe and boiler insulation, we recommend that:

- 9.3** *The Ministry of Labour should ban the application of friable materials containing more than 1% asbestos by weight as insulation for pipes and boilers.*

It appears that a number of asbestos-free materials are available for pipe and boiler insulation, including fibreglass and mineral wool products. Some of these materials were used before asbestos became popular, and others have been developed more recently. In particular, preformed fibreglass and calcium silicate insulation with non-asbestos fibres appear to enjoy widespread popularity for pipe and boiler insulation today. The substitutes seem to perform adequately without substantial cost increases over asbestos products. We review in Chapter 6 the health evidence on mineral wool and fibreglass products. It is not known whether other substitute materials for asbestos-containing pipe and boiler insulation pose health concerns, and we accordingly recommend that:

- 9.4** *The Ministry of Labour should identify the compounds used as substitutes for pipe and boiler insulation, with a view to assessing any health risks associated with these substitutes and to determining what regulations, if any, might be appropriate for the use of these substitutes.*

## **C. Measurement of Asbestos Fibre Levels in Buildings and Outdoors**

In examining exposure levels of occupants and workers in buildings, it is helpful to know something about how these levels are measured. To determine the asbestos fibre concentration in the air, an air sample is drawn through a filter. The material on the filter is then analyzed using either an optical microscope or an electron microscope, and the concentration of material in the air where the sample was taken is estimated.

Three kinds of measurements may be used to quantify the asbestos concentration in the air in buildings. The first is the measurement by the phase contrast microscope (PCM), a form of optical microscope, of the number of fibres (both asbestos and non-asbestos) longer than 5 microns<sup>28</sup> per cubic centimetre (f/cc) of air. This is discussed in Chapter 7 where it is referred to as the "membrane filter method" and is the method used by the Ministry of Labour to specify and enforce the current control limits in a

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<sup>28</sup>While the correct technical term is now micrometre, we will use the more familiar term micron.

fixed workplace. The second measurement method is the use of the transmission electron microscope (TEM) to determine the number of asbestos fibres per cubic centimetre of air. The TEM may be used to count asbestos fibres of all lengths, or only those fibres longer than 5 microns. The third method uses a TEM fibre count to estimate the weight or mass of asbestos fibres in the atmosphere. The mass is expressed in nanograms (one-billionth of a gram) per cubic metre of air ( $\text{ng}/\text{m}^3$ ). We will refer to measurements using all three of these methods.

In Chapter 7 we describe the membrane filter method using PCM to analyze airborne asbestos fibre levels in fixed workplaces. The PCM does not provide a method for identifying what type of fibre has been observed, so that it cannot distinguish between asbestos fibres and other fibres. The PCM yields a fibre count only, *not* a count of asbestos fibres. Fibre identification cannot be achieved without the use of another form of optical microscopy, polarized light microscopy (PLM), or transmission electron microscopy (TEM).

Inability to identify fibre types is not usually a problem in workplaces such as asbestos manufacturing plants, or in buildings during the removal of friable asbestos insulation, because in these instances one can reasonably assume that most fibres in the atmosphere are in fact asbestos fibres. However, in buildings or in the ambient environment where asbestos may represent anywhere from 0 to 100% of the fibres in the air, the PCM is a relatively unreliable means of determining asbestos fibre concentrations. Furthermore, in buildings or outdoors, the majority of the fibres are too thin to be seen by the PCM. This problem arises in the context of fixed workplaces too, but the proportion of thin fibres is generally smaller in fixed workplaces.

Thus, the result of an optical fibre count performed on a building or an environmental sample can be challenged in two ways. If the fibre count is low, it does not establish that asbestos is not present, since there may have been asbestos fibres with diameters too small for detection. If the fibre count is high, it may be argued that few if any of the fibres were actually asbestos, and that most belonged to some other fibrous species. Only when the fibre count is high enough for reliable counting by PCM, perhaps  $0.5 \text{ f/cc}$ , and when there is reason to believe that most fibres in the air are asbestos, as during asbestos insulation removal, is PCM air monitoring useful in buildings. Even then it leaves thin fibres uncounted.

Chatfield has reported that it is widely accepted that the PCM method is not well suited to the measurement of asbestos fibres in the ambient atmosphere: "The U.S. National Institute for Occupational Safety and Health recommends against the use of optical microscopy techniques for monitoring of ambient atmosphere. Many others also reject the use of PCM for environmental measurements, whether inside or outside buildings,

and the U.S. Environmental Protection Agency has specified a method based on transmission electron microscopy (TEM) for asbestos measurements in ambient atmospheres."<sup>29</sup>

The transmission electron microscope is the preferred instrument for analyzing the low asbestos fibre content of building or outdoor air samples. A modern TEM has a resolution of about 0.2 nanometres, which is more than adequate for resolving the smallest fibres of chrysotile, which are about 40 nanometres in diameter.<sup>30</sup> The TEM image also permits observation of some of the internal structure of each fibre. Several methods of identifying the type of fibre observed are available on the TEM, as will be indicated later.

Although the TEM is a sophisticated and precise instrument, capable of observing and identifying very small asbestos fibres, its use for determining airborne asbestos concentrations is beset with difficulties. These difficulties lend uncertainty to the resulting fibre counts. The problems inherent in using a TEM may be seen from a brief review of the procedure for preparing and analyzing TEM samples.

Two types of filters may be used for gathering air samples for TEM analysis, each appropriate for a particular preparation method. The Nuclepore filter has a flat surface and is used for "direct preparation," in which the exposed filter is given a carbon-coating on top which captures the fibres for examination in the TEM. Chatfield, in his work at the Ontario Research Foundation, uses this method for building and environmental samples. This method has the advantage that fibres are observed in the position in which they were first captured on the filter with a minimum of disturbance. A disadvantage is that if the filter is handled roughly in the field, before carbon-coating, fibres may be dislodged and lost.

Alternatively, one may use a cellulose ester (Millipore) filter which has a spongy surface and is used for "indirect" preparation. While various indirect preparation methods have been used, many have now been discredited because they lost asbestos fibres or because asbestos fibre contamination was introduced during the process. Some researchers use an ashing method in which the cellulose filter is ashed, which removes all

<sup>29</sup>Eric J. Chatfield, *Measurement of Asbestos Fibre Concentrations in Ambient Atmospheres*, Royal Commission on Asbestos Study Series, no. 10 (Toronto: Royal Commission on Asbestos, 1983), p. 18.

<sup>30</sup>Eric J. Chatfield, "The Problems of Measurement of Asbestos," in Ontario, Royal Commission on Asbestos, *Proceedings of The Royal Commission on Asbestos Second Public Meeting, Friday, December 12, 1980*, reported by Lydia Dotto (Toronto: Royal Commission on Asbestos, 1981), Appendix A, p. 12. The structures of amosite and crocidolite fibres are different from that of chrysotile, so there is no minimum irreducible fibre size, as there is for chrysotile.

particulates except indestructible material which is predominantly asbestos. The ash is then dispersed in water and refiltered for direct preparation. This ashing and redispersal provides a uniform fibre distribution on the surface of a filter that is well suited for TEM work. However, fibre bundles may be broken up into more numerous fibres so that the resulting fibre count may be higher than it would have been with direct preparation. There is also some concern that fibres may be lost or added if the process is not performed very carefully.

Once a sample is prepared, using either of the above methods, the fibres may be counted on a TEM in a manner similar to that used for optical fibre counting, except that each fibre is subjected to an identification process so that only asbestos fibres are counted. Because building and outdoor samples may include a large proportion of non-asbestos fibres, the identification step is very important.

Chrysotile may be identified by appearance (morphology) alone if there is no suspicion that materials of similar appearance are present. Identification of individual fibres can also be achieved by using selected area electron diffraction (SAED), in which a pattern characteristic of the crystal structure of the fibre is produced in the microscope. However, since the crystal structures of the amphiboles — tremolite, actinolite, crocidolite, anthophyllite, and amosite — are practically identical, it is not possible to distinguish among these minerals using SAED alone. Discrimination among the amphiboles can only be achieved reliably by measurement of the chemical composition of the fibres. Energy dispersive x-ray analysis (EDXA) equipment, which can be incorporated into the TEM, allows these composition data to be obtained for each fibre in addition to obtaining the diffraction patterns. Because outdoor and building air samples may contain a wide variety of fibre types it is important to examine carefully the fibre identification method used.

The results of a TEM analysis of an air sample can be presented as a fibre concentration measured in fibres per cubic centimetre. Because the length and diameter of each fibre is recorded, the fibre count can be presented as the total number of fibres per cubic centimetre observed and as the number of fibres longer than 5 microns per cubic centimetre observed. Any time that fibres longer than 5 microns are found, many short fibres will also be present, so the total fibre count is often 10 or 100 times as great as the count of fibres over 5 microns. As well, because the TEM can detect fine fibres it may produce a count of fibres longer than 5 microns that is much greater than the corresponding count obtained by PCM. (See Section D.3 of this chapter regarding the conversion of TEM fibre counts to equivalent optical counts.)

The same data could be used to determine the mass of asbestos observed. The length and diameter of a fibre can be used to determine fibre

volume. Once the fibre is identified, its density is known, and multiplying the fibre volume by density yields the mass of the fibre. While a fibre count is usually presented in fibres per cubic centimetre, a mass measurement is presented in nanograms per cubic metre of air. A nanogram is one-billionth ( $10^{-9}$ ) of a gram. Note that even when mass measurements of asbestos concentrations in the air are presented, they are derived not from weighing the asbestos, but rather from estimating its weight based upon the dimensions and density of every fibre counted.

Chatfield has reported that there is as yet no international agreement on the appropriate method for measuring asbestos fibre concentrations in the ambient or building air.<sup>31</sup> While work is currently in progress to develop standardized methods, they may not be agreed upon for several years. In the meantime, we must rely upon data from different researchers, prepared by very different methods, which are not easily comparable to each other. Thus, although the TEM may be the best equipment for analyzing ambient or building air samples, the inter-laboratory differences in analytical procedure cause considerable inter-laboratory differences in reported airborne asbestos concentrations.

## **D. Exposure of Occupants and Workers in Existing Buildings**

The principal source of asbestos fibres in the air of existing buildings is the release of fibres from damaged or disturbed friable insulating material. Sawyer and Spooner have identified three modes of contamination of building air by asbestos fibres from such material. They are:

- (i) fallout or erosion, in which asbestos fibres fall from the insulating material or are blown loose from it by air flow;
- (ii) physical contact with the surface of the material, which breaks some material loose; and
- (iii) secondary dispersion or re-entrainment, which is the disturbance of asbestos fibres which have already fallen onto building surfaces, by normal building activity or building cleaning.<sup>32</sup>

It appears that fallout and erosion generally produce minimal levels of fibre concentration in building air. Impact can produce higher fibre

<sup>31</sup> Chatfield, *Measurement of Asbestos Fibre Concentrations in Ambient Atmospheres*, p. 95.

<sup>32</sup> Robert N. Sawyer and Charles M. Spooner, *Sprayed Asbestos-Containing Materials in Buildings: A Guidance Document, Part 2*, prepared for the U.S. Environmental Protection Agency, March 1978, EPA-450/2-78-014 (Washington, D.C.: U.S. Environmental Protection Agency, March 1979), pp. I-2-5, I-2-7.

levels, though generally for very short periods of time. Secondary dispersion can cause significant fibre levels, particularly if substantial amounts of asbestos material have fallen onto the floor or other building surfaces.

We will now review the available data on the fibre levels that building occupants and building workers may experience.

## D.1 Studies Using the Optical Microscope

Pinchin summarized the results of several optical microscopy studies of building atmospheres.<sup>33</sup> He reported that the South Australian Health Commission found levels of airborne fibre in buildings containing sprayed asbestos-containing material under normal conditions to be very similar to fibre levels in buildings without asbestos; the average background fibre level in buildings without sprayed asbestos was reported as 0.03 f/cc, with a maximum amount of 0.05 f/cc. Only 2 asbestos-containing buildings out of 11 in this study yielded fibre levels of 0.1 f/cc or greater. However, when maintenance employees in these buildings moved ceiling tiles or worked above the ceiling in a ceiling space containing sprayed asbestos, they were exposed to fibre levels which rose to approximately 1 f/cc, with a maximum of 5.45 f/cc, using personal samples on the maintenance workers.<sup>34</sup> It should be emphasized that, because of the limitations of the optical microscope, there is no way of knowing what proportion of these observed fibres were asbestos and what proportion were other dusts.

Sawyer found results similar to those of the South Australian Health Commission, with fibre levels of 0.2 f/cc and below in a library during normal activity or no activity. During cleaning of books, replacing of light bulbs, sweeping, dusting, and work on hanging lights, dust levels ranged from 1 f/cc to a maximum of 17.7 f/cc. The library building had been sprayed with a mixture of asbestos (15% by weight of the mixture being chrysotile), fibreglass, and cement binder, much of which was within reach of library users and in poor condition.<sup>35</sup> Again, it is not known what portion of the recorded fibres were in fact asbestos fibres.

Other optical microscope studies surveyed by Pinchin showed fibre levels below 0.3 f/cc with normal activity and above 2 f/cc during high activity, disturbance of the asbestos-containing insulation, and cleaning

<sup>33</sup>Pinchin, *Asbestos in Buildings*, Table III, pp. 1.11–1.12.

<sup>34</sup>D.J. Hamilton, "Asbestos Insulation in South Australian Buildings: Hazard Assessment and Control Experience," draft paper prepared for the South Australian Health Commission [Canberra], 1980. (Mimeographed.) Note that the detection limit for optical measurement is about 0.1 f/cc, so the reported concentrations below this level should be regarded as subject to considerable uncertainty.

<sup>35</sup>Robert N. Sawyer, "Asbestos Exposure in a Yale Building: Analysis and Resolution," *Environmental Research* 13:1 (February 1977): 153.

operations. Considering all the data, Pinchin concluded that under normal conditions fibre levels are quite low in buildings unless the sprayed material is in unusually poor or exposed condition, and even then low fibre levels are sometimes measured. However, maintenance activities and dry cleaning methods consistently raise airborne fibre levels substantially, although optical microscope methods do not allow the determination of the asbestos content of these higher dust levels.

It must be emphasized that optical microscopy fibre level measurements do not distinguish between asbestos and non-asbestos dust. Accordingly, optical microscopy results indicate the highest possible levels of asbestos fibres large enough to be seen by the optical microscope, rather than actual asbestos fibre levels. There are, however, significant limits on the kinds of fibres that are visible under an optical microscope; in addition to not counting fibres shorter than 5 microns, the optical microscope misses fibres thinner than about 0.3 microns.

## D.2 Studies Using the Transmission Electron Microscope

There are several TEM studies of airborne asbestos fibre levels in buildings. Sebastien et al., using TEM methods, compared asbestos fibre levels in the outdoor air in Paris, in buildings without asbestos, and in buildings with sprayed asbestos insulation. Sebastien defined “abnormally high” asbestos concentrations as those above the concentration found in 99% of his outdoor samples. Applying this definition to his 161 outdoor samples, he concluded that fibre levels above 7 ng/m<sup>3</sup> were “abnormally high.” This is consistent with his analysis of 7 buildings without sprayed asbestos insulation in which he found an average of 1.9 ng/m<sup>3</sup>. The highest single reading in a building that did not contain asbestos was 12 ng/m<sup>3</sup>.<sup>36</sup>

Sebastien analyzed 21 buildings that contained sprayed asbestos insulation, collecting 127 air samples. In 9 out of the 21 buildings, the maximum concentration of asbestos fibres was less than 7 ng/m<sup>3</sup> and therefore not “abnormally high.” Of the remaining 12 buildings, there was at least one sample above the 7 ng/m<sup>3</sup> level in each building. The 8 highest samples, found in 4 buildings, exceeded 100 ng/m<sup>3</sup>, and 6 samples exceeded 400 ng/m<sup>3</sup>. The average (arithmetic mean) asbestos fibre concentration in the 21 buildings ranged from 1 to 70 ng/m<sup>3</sup>, with the worst single measurement at 751 ng/m<sup>3</sup>, and 50% of all samples below 5 ng/m<sup>3</sup>. These data are summarized in Table 9.4 in Section D.4 of this chapter. An analysis of air in various buildings during normal use demonstrated that “abnormally high”

<sup>36</sup>Patrick Sebastien et al., *Measurement of Asbestos Air Pollution Inside Buildings Sprayed with Asbestos*, translation of document prepared for the Government of France, Ministry of Health and Ministry for the Quality of Life Environment, 1977, EPA-560/13/80-026 (Washington, D.C.: U.S. Environmental Protection Agency, August 1980), p. 59.

asbestos fibre levels were more common in buildings with soft, fibrous asbestos than with cementitious asbestos material, and that fibre levels were particularly elevated in buildings with obvious material deterioration or with exposed material and high levels of activity.

Nicholson, Rohl, and Weisman used rather different analytical techniques to examine outdoor air, buildings without asbestos, and buildings with sprayed asbestos insulation.<sup>37</sup> (See Table 9.4.) Of 23 samples of outdoor urban air, Nicholson found 19, or 83%, below 20 ng/m<sup>3</sup> of asbestos. Twenty-two readings, or 96%, were below 50 ng/m<sup>3</sup>, with a maximum reading of 87 ng/m<sup>3</sup>. It is interesting to note that in comparison with Sebastien, 99% of Nicholson's outdoor readings would not be below 7 ng/m<sup>3</sup>, but below 87 ng/m<sup>3</sup>. This means that Sebastien's definition of "abnormally high" asbestos concentrations, when applied to Nicholson's data, would involve readings of above 87 ng/m<sup>3</sup>. Nicholson took 12 samples in 2 buildings that did not contain sprayed asbestos insulation. Here he found 11 samples, or 92%, below 20 ng/m<sup>3</sup>, and a maximum concentration of 42 ng/m<sup>3</sup>. Thus, the asbestos fibre concentration measured by Nicholson in the air of buildings without asbestos-containing insulation was above zero, but still somewhat lower than that measured in the outdoor air.

In the same study, Nicholson examined 17 buildings containing sprayed wet-applied or dry-applied asbestos. Of 28 samples taken in buildings with wet-applied asbestos, 26, or 93%, contained less than 20 ng/m<sup>3</sup> of asbestos. Most of these readings were in the 5 to 20 ng/m<sup>3</sup> range. Only one sample contained more than 50 ng/m<sup>3</sup> and it measured 180 ng/m<sup>3</sup>. Nicholson concluded that buildings with sprayed wet-applied asbestos do not have fibre levels significantly above outdoor concentrations. However, in buildings containing sprayed dry-applied asbestos, of 53 samples, 28, or 53%, contained less than 20 ng/m<sup>3</sup> of asbestos, again mostly in the 5 to 20 ng/m<sup>3</sup> range. Forty-four samples, or 83% of the total, were less than 50 ng/m<sup>3</sup>; while 2 samples, or 4%, exceeded 200 ng/m<sup>3</sup>. The highest measurement was 830 ng/m<sup>3</sup> in a generator room, not frequented by general building occupants. The next highest measurement was 210 ng/m<sup>3</sup>. Nicholson concluded that the airborne asbestos fibre levels in buildings with dry-applied asbestos spray are significantly above those in buildings without asbestos or in the outdoor air.

Sawyer and Spooner reported on a small number of measurements of asbestos fibre levels in buildings containing exposed sprayed asbestos-containing insulation, using TEM methods.<sup>38</sup> Three air samples in a Connecticut office building during normal activity yielded an average con-

<sup>37</sup> William J. Nicholson, Arthur N. Rohl, and Irving Weisman, *Asbestos Contamination of the Air in Public Buildings*, EPA-450/3-76-004 (Research Triangle Park, N.C.: U.S. Environmental Protection Agency, October 1975), Table 4, p. 24.

<sup>38</sup> Sawyer and Spooner, *Sprayed Asbestos-Containing Materials in Buildings: A Guidance Document*, p. I-2-9.

centration of 79 ng/m<sup>3</sup> and a maximum of 110 ng/m<sup>3</sup>. Studies in New York office buildings containing asbestos-containing insulation yielded an average in the building with the lowest asbestos levels of 2.5 ng/m<sup>3</sup> and in the most contaminated building of 200 ng/m<sup>3</sup>. No details are available on the number of samples, the number of buildings, or the method of measurement. Sawyer and Spooner also reported on fibre levels measured in buildings with custodial activity that disturbs settled asbestos fibres, revealing considerably higher concentrations of 643 ng/m<sup>3</sup> in one building, and 296 ng/m<sup>3</sup> in another.<sup>39</sup> In general, the readings presented by Sawyer were higher than those of either Sebastien or Nicholson, although less information about the method of taking the samples and analyzing them was provided by Sawyer than by the other researchers.<sup>40</sup>

Pinchin conducted a study for this Commission of airborne asbestos fibre levels in Ontario buildings, in which he collected air samples that were analyzed by Chatfield at the Ontario Research Foundation, using a TEM. Table 9.1 reports on asbestos fibres detected in 19 buildings, counting both asbestos fibres of all lengths and asbestos fibres longer than 5 microns. While all buildings contained asbestos insulation, only 5 yielded detectable asbestos fibres longer than 5 microns. All fibre levels reported were extremely low, whether measured in ng/m<sup>3</sup> or in f/cc, despite the high resolution of the electron microscope. The highest concentration of fibres longer than 5 microns is 0.003 f/cc. The fibre concentrations reported in Table 9.1 may be compared to those in the outdoor environment reported in Chapter 11; the building concentrations are similar to prevailing outdoor fibre concentrations.

Since the TEM can detect fibres not seen with an optical microscope, these fibre levels can safely be interpreted as less than 1% of both Ontario's recently adopted 1 f/cc workplace control limit for chrysotile and the 0.5 f/cc control limit for amosite. On the other hand, in all of these buildings there was no particular disturbance to the asbestos-containing material, so that peak concentrations could be generated considerably above the levels shown in Table 9.1.

Table 9.2 shows the results of monitoring the air in Ontario buildings containing asbestos insulation while work was being performed, using great care to minimize fibre release. Both the optical microscope and the TEM were used for analysis. The top half of the table indicates fibre levels during inspection above a suspended ceiling, and the bottom half indicates fibre levels during minor maintenance or renovation of a suspended ceiling. The optical microscope counts are all quite low when compared with the recently adopted 1 f/cc control limit for chrysotile, despite the fact that fibres other than asbestos may well be included in these counts. These

<sup>39</sup>Ibid.

<sup>40</sup>For a summary of these three studies, see Pinchin, *Asbestos in Buildings*, Table IV, p. 1.17.

Table 9.1  
Results of Air Monitoring Using Transmission Electron Microscopy in Nineteen Ontario Buildings

Building No.	Number of Samples	Asbestos Fibres of All Lengths f/cc	Asbestos Fibres >5.0 $\mu\text{m}$ f/cc	Asbestos Type
1	4	0.0007	0.59	amosite
2	5	0.006	3.0	chrysotile
3	1	0.004	0.026	chrysotile
4	3	0.003	0.067	amosite
5	5	0.0	0.0	chrysotile
6	3	0.015	1.7	amosite
7	5	0.01	0.017	chrysotile
8	3	0.004	0.31	chrysotile
9	2	0.20	0.004	chrysotile
10	4	0.01	0.045	chrysotile
11	7	0.009	11.	chrysotile
12	3	0.023	3.3	amosite
13	2	0.010	0.027	chrysotile
14	4	0.016	2.7	amosite
15	1	0.059	8.0	chrysotile
16	2	0.003	0.012	chrysotile
17	4	0.027	0.70	chrysotile
18	1	0.010	0.13	amosite
19	4	0.001	0.016	amosite

**Note:** \*The figure 0.0 indicates that no fibres were detected; the concentration is therefore below the detection limit for that sample.

**SOURCES:** Data in last column of this table are from: Personal communication between Dr. Donald J. Pinchin, D.J. Pinchin Technical Consulting Ltd. and Royal Commission on Asbestos Staff, 14 December 1982.  
Other data in this table are adapted from: Donald J. Pinchin, *Asbestos in Buildings*, Royal Commission on Asbestos Study Series, no. 8 (Toronto: Royal Commission on Asbestos, 1982), Table II, p. 6.7.

Table 9.2  
Air Monitoring Results During Inspection or Maintenance

Sample Location	Personal or Area	Optical Microscopy (PCM) f/cc	Transmission Electron Microscopy			
			Total Asbestos Fibres		Asbestos Fibres > 5.0 μm	
			f/cc	ng/m³	f/cc	ng/m³
Inspection above suspended ceiling						
Inspector	P	0.31	0.152	14.7	<0.02	—
Observer	P	0.15	0.39	460.7	0.016	420
Background	A	<0.009	0.066	3.3	<0.008	—
Background	A	0.009	0.092	1.6	<0.008	—
Maintenance, renovation above suspended ceiling						
Worker above ceiling	P	0.17*	370	6,400	12.0	1,100
Assistant	P	0.05	2.68***	104***	<0.07***	—
Close to work site	A	0.009*, **	0.179	2.6	<0.02	—
Far from work site	A	<0.005**	0.118	8.0	<0.006	—

Notes: \* Average of 2 samples.

\*\* These figures are probably below the limit of reliable detection.

\*\*\* Approximate.

SOURCE: Adapted from Donald J. Pinchin, *Asbestos in Buildings*, Royal Commission on Asbestos Study Series, no. 8 (Toronto: Royal Commission on Asbestos, 1982), Tables I and II, pp. 7.5, 7.8.

optical counts are also low in comparison with those found by other researchers and discussed earlier in this section, probably because of the great care to minimize fibre release with which the work was performed.

Turning to the TEM results, and considering only asbestos fibres longer than 5 microns, the asbestos concentration is negligible in 6 out of 8 cases. Only one of the readings, that of the personal sample on the maintenance worker above the ceiling, yields a concentration of fibres, longer than 5 microns, that exceeds the 1 f/cc workplace control limit for chrysotile. As we note above, the electron microscope can detect many fibres not observed under the optical microscope, and the corresponding optical count is below the 1 f/cc standard for chrysotile. If the mass measurements of asbestos fibres of all lengths are considered, 5 of the 8 readings are above the 7 ng/m<sup>3</sup> level established as “abnormally high” for outdoor air by Sebastien, although this comparison may not be meaningful, as Sebastien used different analytic methods. With the exception of the personal sample on the worker above the ceiling, these TEM results are generally low compared to results of other studies, perhaps because of the care with which the maintenance work was performed, or perhaps because care was taken to count only identified asbestos fibres.

Three of the mass measurements shown in Table 9.2 — 460.7; 6,400; and 104 ng/m<sup>3</sup> — are considerably higher than the rest. Two of these high readings are associated with high fibre counts, while one, 460.7 ng/m<sup>3</sup>, is not. An explanation for the lack of correlation in this one case is that a large asbestos fibre or fibre bundle would be counted as a single fibre, but might have considerable mass.

The Ontario data presented in Tables 9.1 and 9.2 are consistent with other studies suggesting that maintenance and inspection activities in the vicinity of asbestos insulation can substantially increase asbestos fibre concentrations in the air.

### **D.3 Conversion of Transmission Electron Microscopy Results into Optical Fibre Count Equivalents**

Earlier in this chapter we identified the three methods of measuring the concentration of asbestos fibres in the air of buildings. These are: measurement of the number of fibres per cubic centimetre of air determined by the optical microscope; measurement of the number of asbestos fibres per cubic centimetre of air determined by the TEM; and measurement of the mass of asbestos fibres in the air by the TEM and expressed as nanograms per cubic metre. Epidemiological studies that relate asbestos exposure to human health express the asbestos exposure in terms of f/cc measured by the optical microscope, or in terms of particle counts, but rarely in terms of mass measurement. In order to assess the possible health

effects of the asbestos exposure of building occupants, it would be useful to express that exposure in f/cc as measured by the optical microscope. Yet it has been demonstrated that the optical microscope cannot be used reliably to measure asbestos fibre concentrations in building air. Thus, we must start with TEM measurements and attempt to estimate what their equivalent optical fibre counts would be. We will first consider TEM fibre counts and then TEM mass measurements.

There are two sources of divergence between a TEM count of asbestos fibres longer than 5 microns and the fibre count that would be observed by an optical microscope (PCM) using the standard workplace measuring technique, even when both relate to atmospheres with only asbestos fibres. First, the preparation of a TEM specimen is different from that of an optical microscope slide. Fibre bundles may be broken up into individual fibres in the indirect preparation of TEM specimens, or fibres may be lost. Specimens may become contaminated by asbestos in the laboratory. Current data are insufficient to indicate whether the net effect of these differences in sample preparation will increase or decrease a TEM fibre count relative to a PCM fibre count. Second, the TEM can detect fibres much finer than the thinnest fibres visible under the PCM. Dr. Eric J. Chatfield testified before this Commission that the PCM detects only between 2 and 25% of the fibres longer than 5 microns which would be detected by TEM. Thus, for a given air sample, the optical fibre count might be only 2 to 25% as high as a TEM fibre count.<sup>41</sup> In a subsequent study of asbestos fibres in the Stockholm subway, Chatfield found that of the fibres longer than 5 microns, one-third were sufficiently thick to be visible in an optical microscope.<sup>42</sup> Here the major source of asbestos fibres was thought to be the brake linings of the subway cars, rather than asbestos insulation. Outdoor samples, or samples of indoor air in undisturbed buildings, contain so few asbestos fibres longer than 5 microns that it is not possible to analyze the distribution of fibre thickness and thus to determine reliably the proportion of fibres detected by the TEM that could be seen by an optical microscope. While the actual numbers in particular cases could be as low as 2% or as high as 50%, we conclude that 10% is the best single number to represent this proportion. This implies that a TEM count of fibres longer than 5 microns should be divided by 10, on average, to determine the equivalent optical fibre count.

Pinchin's data in Table 9.2 contain a set of optical fibre counts and TEM counts of fibres longer than 5 microns. The optical counts may be inflated by non-asbestos fibres. The ratio of TEM fibres to optical fibres ranges from a high of 70 to a low of 0.06, with an average of about 17. The variations in these ratios arise from differences in analytical methods, non-

<sup>41</sup> RCA Transcript, Evidence of Dr. Eric J. Chatfield, 9 July 1981, Volume no. 18, p. 140.

<sup>42</sup> Personal communication between Dr. Eric J. Chatfield, Ontario Research Foundation and Royal Commission on Asbestos Staff, 27 June 1983.

asbestos fibres in the PCM data, and the inability of the optical microscope to detect very thin fibres. We interpret them as providing some support for adopting as a rough guideline the assumption that a TEM count of fibres longer than 5 microns should be divided by 10 to estimate the count of fibres that would be detected by PCM. They also show the huge variability in the relationship between the TEM and PCM fibre counts.

Other researchers using the TEM report only the total mass of asbestos and not a fibre count. Can these mass measurements be converted to an equivalent optical fibre count? If every asbestos fibre were the same size (and thus mass), then any mass measurement would represent a specific number of fibres. However, asbestos fibres are of widely varying sizes. Still, if all air samples contained the same proportion of fibres of varying sizes, then it should be possible to determine an average relationship between the number of fibres of asbestos and the mass of those fibres. If this average relationship could be determined, it could be used to convert mass measurements to fibre counts.

Unfortunately, we cannot be confident that the distribution of asbestos fibre sizes is the same in all samples analyzed. The size distribution of fibres will depend upon the type of asbestos involved, the product it is in, and the process generating the dust. Manufacturing may generate different fibre size distributions than the spraying of building insulation or disturbing building insulation. Even in buildings, different types of insulation, or different types of disturbance to that insulation, may release fibres of different sizes and therefore with different fibre to mass ratios. In order to reduce the variability of fibre size distributions, we will concentrate on the measurement of asbestos mass and fibre levels generated by insulation in buildings.

Another problem arises because there is no standard method for making and analyzing mass measurements. Each researcher has developed his own technique for collecting samples and performing the analytical work in the laboratory. Accordingly, the mass measurements made by different researchers are not necessarily comparable. One could hardly expect incomparable mass measurements to be converted to comparable fibre counts.

The conversion between optically visible asbestos fibres longer than 5 microns and asbestos mass is generally expressed as the number of fibres per nanogram of asbestos (f/ng). This means that 1 nanogram of asbestos collected from the air would on average contain the specified number of optically visible fibres. However, measurements of asbestos concentration in the air are expressed in fibres per cubic centimetre and in nanograms per cubic metre. One cubic metre contains 1 million cubic centimetres and therefore 1 million times as many nanograms of asbestos as 1 cubic centimetre. This may be demonstrated by the following example: Consider a conversion of 20 fibres longer than 5 microns measured optically per nano-

gram. If we measure 1 f/cc optically, there will be 1/20 nanogram per cubic centimetre (ng/cc). However, since there are 1 million cubic centimetres per cubic metre, there will be (1 million x 1/20) 50,000 ng/m<sup>3</sup> of asbestos in the air. Thus, 20 f/ng implies that 1 f/cc equals 50,000 ng/m<sup>3</sup>. Alternatively, if 30 fibres weigh 1 nanogram, then 1 f/cc equals 33,000 ng/m<sup>3</sup>.

Recognizing the limitations discussed above on our ability to convert mass measurements to fibre counts, let us consider the evidence in an attempt to arrive at a conversion factor. Table 9.3 shows the conversions that have been used and derived in other studies. The U.S. EPA reviewed the available evidence and concluded that it was most likely that in building atmospheres 30 fibres of asbestos weigh 1 nanogram, and that 1 nanogram would in any event contain no less than 20 fibres. Dr. William J. Nicholson, as well, stated in his testimony before this Commission that 30 fibres could be regarded as equivalent in weight to 1 nanogram of asbestos.<sup>43</sup> Sebastien, who has conducted extensive mass measurements in buildings, has quoted other studies on the proposition that 2 f/cc measured optically are approximately equal to 100,000 ng/m<sup>3</sup> based on TEM analysis.<sup>44</sup> This conversion means that 1 nanogram of asbestos contains 20 fibres.

Pinchin relied upon electron microscopy performed by Chatfield at the Ontario Research Foundation to measure both the number of fibres greater than 5 microns and the mass of all asbestos fibres. In samples taken from 19 buildings, Pinchin reported data which imply an average of 592 f/ng of asbestos.<sup>45</sup> Analyzing the buildings with amosite separately from those with chrysotile yields 808 f/ng for amosite and 43 f/ng for chrysotile. If the TEM can detect 10 times as many fibres as the PCM, a conversion factor of 59.2 f/ng (optical/electron microscope) is implied by the average of 592 f/ng (electron/electron microscope). Note, however, that when Pinchin used optical measurements alongside TEM mass measurements, the total of his optical fibre counts and the total of his TEM mass measurements implied a conversion factor of 102 f/ng. (See Table 9.2.)

The studies listed at the bottom of Table 9.3 examine the relation of mass to fibre counts in manufacturing workplaces. While these show some consistency with the building data, we do not rely on them for drawing conclusions about building atmospheres.

As the numbers of Table 9.3 show, there is an enormous range in possible conversion factors. Furthermore, there are very few original studies

<sup>43</sup>RCA Transcript, Evidence of Dr. William J. Nicholson, 29 June 1981, Volume no. 14, p. 100.

<sup>44</sup>Sebastien et al., *Measurement of Asbestos Air Pollution Inside Buildings Sprayed with Asbestos*, p. 26.

<sup>45</sup>Pinchin, *Asbestos in Buildings*, Table II, p. 6.7.

Table 9.3  
Relationship Between Fibre Counts and Mass Measurement

Study	Location	f/ng*	
		EM/EM	OM/EM
Studies in Buildings			
U.S. EPA**a	Buildings		30
Sebastien**b	Buildings		20
Pinchin <sup>c</sup>	Buildings	592	
	Buildings		102
Studies in Factories***			
Dement and Harris <sup>d</sup>	Pipe manufacturing (estimated)	76-134	
Winer and Cossette <sup>e</sup>			9.1
			36.0
Rohl et al. <sup>f</sup>	Brake maintenance (6 samples)		770
	Brake grinding (2 samples)		62
Bruckman and Rubino**g	Not specified		20

**Notes:** \*Fibres counted by electron microscope (EM) or optical microscope (OM). Mass measured by electron microscope (EM).  
 \*\*Not calculated directly from empirical work, but determined on the basis of other studies.  
 \*\*\*These studies are not directly relevant to the conversion of building measurements since they are based on industrial dust measurements.

Table 9.3 (continued)  
Relationship Between Fibre Counts and Mass Measurement

SOURCES: Adapted from:

- <sup>a</sup> U.S., Environmental Protection Agency, Office of Toxic Substances, *Support Document for Final Rule on Friable Asbestos-Containing Materials in School Buildings: Health Effects and Magnitude of Exposure* (Washington, D.C.: U.S. Environmental Protection Agency, January 1982), p. 95.
- <sup>b</sup> Patrick Sebastien et al., *Measurement of Asbestos Air Pollution Inside Buildings Sprayed with Asbestos*, translation of document prepared for the Government of France, Ministry of Health and Ministry of the Quality of Life Environment, 1977, EPA-560/13/80-026 (Washington, D.C.: U.S. Environmental Protection Agency, August 1980), p. 26.
- <sup>c</sup> Results calculated from data presented in Donald J. Pinchin, *Asbestos in Buildings*, Royal Commission on Asbestos Study Series, no. 8 (Toronto: Royal Commission on Asbestos, 1982), Table II, p. 6.7.
- <sup>d</sup> John M. Dement and Robert L. Harris, Jr., *Estimates of Pulmonary and Gastrointestinal Deposition for Occupational Fiber Exposures*, U.S. Department of Health, Education and Welfare, National Institute for Occupational Safety and Health, Publication no. 79-135 (Cincinnati, Ohio: DHEW/NIOSH, April 1979), pp. 56-58.
- <sup>e</sup> Winer and Cossette, 1979, cited in Source d, Table 25, p. 94.
- <sup>f</sup> Arthur N. Rohl et al., "Asbestos Exposure During Brake Lining Maintenance and Repair," *Environmental Research* 12 (1976): 125. Data calculated by averaging the data in Table 5, p. 125.
- <sup>g</sup> Leonard Bruckman and Robert A. Rubino, "Asbestos: Rationale Behind a Proposed Air Quality Standard," *Journal of the Air Pollution Control Association* 25:12 (December 1975): 1209.

based on empirical fibre counting in buildings. This means that a single conversion factor must be subject to considerable uncertainty. We will use the 30 f/ng conversion that has been suggested by the U.S. EPA, recognizing that in individual measurements the actual relationship might be reflected by a higher or lower number. This conversion suggests more fibres per nanogram than Sebastien's suggestion of 20, but fewer than Pinchin's 102.

As noted above, if there are 30 fibres longer than 5 microns measured optically per nanogram of asbestos in buildings, then a fibre concentration of 1 f/cc would imply a mass density of 33,000 ng/m<sup>3</sup>.

The most conservative conversion factor between optical fibres and TEM mass would be the highest factor based on building data, which is 102 f/ng, calculated from Pinchin. Using this conservative conversion factor yields the highest estimate of fibre exposure, and thus the highest estimate of health risks. This is almost certainly too high, since the optical measurements presumably contain some non-asbestos fibres. We will rely on the conversion factor of 30 f/ng because we believe that it is the best single estimate of the true relationship. We will present some calculations using the conservative conversion factor to show the outer limit of possible risks, although we believe it unlikely to represent the actual risks.

Although we have adopted a conversion factor to allow us to express mass measurements as equivalent optical fibre counts, we still have only an approximate index of health risk because we do not know for certain which fibre sizes are most hazardous, and how well *any* of the measurement methods correlate with the actual hazard.

## D.4 Conclusion

The data presented above suggest that most asbestos fibre exposures in buildings would be equivalent to concentrations of 0.001 f/cc when measured by optical methods. The highest exposures in buildings would be equivalent to less than 0.01 f/cc. We will review the exposure data in the context of these two numbers to test their validity as benchmarks for describing the exposure of building occupants to asbestos fibre concentrations.

We summarize the available data in Table 9.4, with mass measurements converted to optical fibre counts, recognizing the uncertainty that attends any attempt at conversion. Here we use the conversion of 30 fibres measured optically per nanogram of asbestos, which means that 1 f/cc equals 33,000 ng/m<sup>3</sup>. The data from Sebastien show that in buildings with sprayed asbestos insulation, the median exposure level is less than 5 ng/m<sup>3</sup>, or 0.00015 f/cc, and 90% of all measurements are less than 30 ng/m<sup>3</sup>, or

**Table 9.4**  
**Range of Fibre Exposures in Buildings with Asbestos**

<b>Study</b>	<b>Mass Measurement ng/m<sup>3</sup></b>	<b>Equivalent Optical f/cc, assuming that 1 f/cc optical = 33,000 ng/m<sup>3</sup></b>
<b>Sebastien<sup>a</sup></b>		
Outdoors		
— arithmetic mean	0.96	0.00003
— 99% less than	7	0.0002
7 asbestos-free buildings		
— arithmetic mean	1.9	0.00006
21 buildings with spray asbestos		
— lowest building average	1	0.00003
— highest building average	70	0.0021
— highest single reading	751	0.023
— 94% of measurements less than	100	0.003
— 50% of measurements less than	5	0.00015
<b>Nicholson<sup>b</sup></b>		
Outdoors		
— 83% less than	20	0.0006
— 96% less than	50	0.0015
— highest	87	0.0026
2 asbestos-free buildings (12 samples)		
— 92% less than	20	0.0006
— highest	42	0.0013
17 buildings with sprayed asbestos wet-applied (28 samples)		
— 93% less than	20	0.0006
— highest	180	0.0054
dry-applied (53 samples)		
— 53% less than	20	0.0006
— 83% less than	50	0.0015
— 92% less than	100	0.003
— highest	830	0.025
<b>Sawyer and Spooner<sup>c</sup></b>		
Connecticut office buildings		
— average (measurement)	79	0.0024
— highest	110	0.0033
New York office buildings		
— lowest building average	2.5	0.000075
— highest building average	200	0.006
Buildings with disturbing custodial activity		
— school average*	643	0.019
— apartment**	296	0.0089
<b>U.S. EPA<sup>d</sup></b>	57-270	0.0017 - 0.0081
<b>Pinchin<sup>***e</sup></b>		0 - 0.0003

**Notes:** \*Based on two air samples.

\*\*Based on one air sample.

\*\*\*Based on TEM fibre count, and assuming that the TEM detects 10 times as many fibres over 5 microns in length as the optical microscope.

**Table 9.4 (continued)**  
**Range of Fibre Exposures in Buildings with Asbestos**

SOURCES: Adapted from:

<sup>a</sup>Patrick Sebastien et al., *Measurement of Asbestos Air Pollution Inside Buildings Sprayed with Asbestos*, translation of document prepared for the Government of France, Ministry of Health and Ministry for the Quality of Life Environment, 1977, EPA-560/13/80-026 (Washington, D.C.: U.S. Environmental Protection Agency, August 1980), p. 14.

<sup>b</sup>William J. Nicholson, Arthur N. Rohl, and Irving Weisman, *Asbestos Contamination of the Air in Public Buildings*, EPA-450/3-76-004 (Research Triangle Park, N.C.: U.S. Environmental Protection Agency, October 1975), Table 5, p. 25; Table 6, p. 26.

<sup>c</sup>Robert N. Sawyer and Charles M. Spooner, *Sprayed Asbestos-Containing Materials in Buildings: A Guidance Document, Part 2*, prepared for the U.S. Environmental Protection Agency, March 1978, EPA-450/2-78-014 (Washington, D.C.: U.S. Environmental Protection Agency, March 1979), Table I-2-1, p. I-2-9.

<sup>d</sup>U.S., Environmental Protection Agency, Office of Toxic Substances, *Support Document for Final Rule on Friable Asbestos-Containing Materials in School Buildings: Health Effects and Magnitude of Exposure* (Washington, D.C.: U.S. Environmental Protection Agency, January 1982), p. 72.

<sup>e</sup>Donald J. Pinchin, *Asbestos in Buildings*, Royal Commission on Asbestos Study Series, no. 8 (Toronto: Royal Commission on Asbestos, 1982), Table I, p. 7.5; Table II, p. 7.8; Table III, p. 7.12.

0.001 f/cc. We conclude that most buildings with sprayed asbestos insulation expose occupants to less than 0.001 f/cc. The worst building averaged 70 ng/m<sup>3</sup>, or 0.0021 f/cc, and 94% of all measurements in all buildings were less than 100 ng/m<sup>3</sup>, or 0.003 f/cc. In addition, we conclude that the worst building exposures are considerably less than 0.01 f/cc. Even using the conservative factor of 102 f/ng, the median exposure is still less than 0.001 f/cc, and the worst about 0.007 f/cc.

The Nicholson data show that buildings with wet-applied sprayed asbestos do not expose occupants to fibre levels above those of buildings which do not contain asbestos insulation, or above those of the outdoor air. Buildings with dry-applied sprayed asbestos expose occupants on average to less than 20 ng/m<sup>3</sup>, or 0.0006 f/cc. The data show that 92% of all measurements are below 100 ng/m<sup>3</sup>, or 0.003 f/cc. Thus, again we can conclude that the average building containing sprayed asbestos insulation exposes occupants to less than 0.001 f/cc, while the worst may expose occupants to considerably less than 0.01 f/cc. Even using the conservative conversion factor, the average building exposes occupants to about 0.002 f/cc and the worst building to less than 0.01 f/cc.

The data from Sawyer and Spooner are less complete and therefore more difficult to interpret. Still, the worst building exposes occupants to 200 ng/m<sup>3</sup>, or 0.006 f/cc (or 0.02 f/cc using the conservative conversion), while the average building is clearly far below this.

Turning to the data from Pinchin contained in Table 9.1 above, and dividing his TEM fibre counts by 10 to determine the equivalent optical fibre count, we have a range of 0 to 0.0003 f/cc for undisturbed buildings, well below the 0.001 level. Finally, the U.S. EPA concluded that schools that presented the highest exposure risk for occupants might expose occupants to between 57 and 270 ng/m<sup>3</sup> or, using the conversion factor of 30, expose occupants to between 0.0017 and 0.0081 f/cc.<sup>46</sup> The conservative conversion factor of 102 would yield a range of 0.006 and 0.028 f/cc. The EPA relied primarily on the Sebastien data summarized above and seems to have used the highest measurements as if they were averages, not maxima.

In conclusion, studies of buildings which appear to present substantial asbestos problems show a range of fibre concentrations. Converting these to optical fibre count equivalents so that we can compare these fibre levels with the health effects from occupational exposure, we conclude that the majority of exposures of building occupants in buildings with substantial amounts of friable asbestos would be to fibre levels less than 0.001 f/cc, with a few single readings as high as 0.01 f/cc representing the highest likely exposure.

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<sup>46</sup>U.S., Environmental Protection Agency, *Support Document for Final Rule*. . . , p. 72.

How many hours per week do people spend in the types of asbestos-containing buildings discussed above? Such buildings include schools, office buildings, factories, and warehouses, but not, in general, houses or apartment buildings. Most people are in such buildings for a normal workday or less. It follows that the number of hours per week of exposure of building occupants would tend not to exceed the number of hours per week of potential exposure experienced by industrial workers.

For how many years of his life is the average building occupant exposed? Many people will be in buildings which might contain asbestos during their school and working years, which could total up to 60 years. We will conclude in Chapter 10, however, that less than 10% of schools, offices, factories, and warehouses contain sprayed asbestos insulation. Thus, the average person who spends 60 years in these types of buildings would spend on average 1/10 of those years, or 6 years, in buildings with sprayed asbestos insulation. To be conservative, we will assume an average exposure of 10 years, although this is certainly higher than the average. We recognize, however, that some individuals will spend more than 10 years in buildings containing sprayed asbestos insulation.

It is clear from the above data that the exposure of building occupants to asbestos fibres is enormously less than the exposure allowed to industrial workers under the recently adopted Ontario asbestos control limits of 1 f/cc for chrysotile, 0.5 f/cc for amosite, and 0.2 f/cc for crocidolite. The 0.001 f/cc exposure which we conclude to be the highest estimate of the average exposure in such buildings is 1/1,000 of the maximum worker exposure under the control limit for chrysotile. Many of the buildings that contain sprayed asbestos contain a mixture of chrysotile and amosite. The control limit for amosite is 0.5 f/cc. The highest average exposure is 1/500 this amount. In Chapter 7 we recommend that workers not be exposed to amosite at greater concentrations than would occur with a control limit of 0.1 f/cc. The highest average exposure is 1/100 this amount. Taking 0.01 f/cc as the highest likely occupant exposure, this is 1/100 the exposure of the maximum worker exposure under the new occupational control limit for chrysotile. This is 1/50 the maximum worker exposure under the current Ontario amosite control limit and 1/10 the maximum worker exposure under our recommended amosite control limit. Most exposures are less than 20 ng/m<sup>3</sup> which is 1/10,000 of the allowable exposure of 0.2 milligram (200,000 ng/m<sup>3</sup>) allowed under the *Quebec Mining Act*.<sup>47</sup> Asbestos insulation workers and manufacturing workers during the 1950s were exposed to between 1,000 and 10,000 times the asbestos concentrations that current building occupants might experience. One cannot escape the conclusion that the exposure of general building occupants to asbestos fibre concentrations in the air is negligible under most condi-

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<sup>47</sup> *Quebec Mining Act*, R.S.Q. 1977, c. M-13.

tions; the conditions under which those exposures are not negligible are readily identifiable.

The data from Pinchin (Table 9.2 in this chapter), Sawyer (Table 9.4 in this chapter), and others show which conditions can cause elevated fibre levels for building occupants. One such condition is the occurrence of custodial or maintenance work that disturbs friable asbestos-containing insulation. Another condition is the deterioration of insulation so that it falls onto building surfaces and can be disturbed by normal building activity. We conclude that building occupants are not subject to asbestos fibre exposure in excess of a very small fraction of the recently adopted Ontario workplace control limits, except where: (i) the occupant is in the immediate vicinity of work that disturbs friable asbestos-containing insulation; (ii) the occupant is within the range of air circulation of work that disturbs friable asbestos-containing insulation; or (iii) significant quantities of friable asbestos-containing insulation have fallen onto building surfaces and are being disturbed.

We recognize that there are limited data available on the exposure levels of building workers and occupants when maintenance or custodial work is performed on buildings. We anticipate that the implementation of Recommendation 10.22 in the next chapter will shed light on the exposures encountered in the immediate vicinity of building work.

## **E. Risk Assessment for Building Occupants**

If one has developed a model of the dose-response relationship between asbestos fibre exposure and asbestos-related disease, one can use observed exposures to estimate the possible disease that may result from those exposures. This methodology was used in Chapter 7 to estimate the risk to workers caused by different levels of occupational exposure. The risk to building occupants may be similarly estimated, subject to the same high levels of uncertainty in the results. Because there are no reliable epidemiological studies of the health effects of exposures to very low asbestos fibre levels, any risk assessment must involve extrapolation of other data which introduces great uncertainty about the result. We assume a linear dose-response relationship, which, if anything, may overestimate disease.

The U.S. EPA analyzed the health risks to building occupants from exposure to asbestos in a paper first released in 1980 and then released in revised form in 1982. The EPA paper concluded that school buildings containing friable asbestos might expose occupants to airborne asbestos concentrations between 57 ng/m<sup>3</sup> and 270 ng/m<sup>3</sup>, and that because of deterioration of the asbestos in the future, this exposure might rise to 500

ng/m<sup>3</sup>.<sup>48</sup> Custodial and maintenance workers could experience greater exposures because of their work. These exposure estimates were based primarily on the work of Sebastien in France and on only those buildings in his studies with high asbestos levels. We believe that the EPA conclusions overestimated the average exposure of occupants of buildings containing sprayed asbestos insulation, in part because of a selective use of the highest exposures reported by Sebastien. Of the 21 buildings studied by Sebastien, the EPA analyzed only 8, those with the highest airborne asbestos fibre levels of the 21.

The 1982 EPA paper, unlike the 1980 version, did not mention its selective use of data reported by Sebastien. Nor did it mention that in 9 buildings containing sprayed asbestos insulation the maximum asbestos fibre concentration found by Sebastien was 7 ng/m<sup>3</sup> or less; by Sebastien's definition, not "abnormally high." (See the summary of the Sebastien data in Table 9.4.) We find that this selective use of Sebastien's data in the EPA paper resulted in an overestimation of the average exposure of occupants of buildings containing sprayed asbestos insulation.

The EPA study compared the exposure of building occupants to the exposure of building insulation workers who were exposed to the same types of fibres. The average working exposure of insulation workers, as calculated by the EPA, ranged from 3 to 15 f/cc, with an average estimated exposure of 9 f/cc.<sup>49</sup> The study determined that 30 fibres measured optically are equivalent to 1 ng measured by the TEM.<sup>50</sup> Insulation workers thus received a lifetime exposure of between 2 million and 10 million nanograms per cubic metre-years (ng/m<sup>3</sup>-yrs). A student who spends 6 years in a school will be exposed, multiplying the exposure of 57 or 270 ng/m<sup>3</sup> by 6, to between 342 and 1,620 ng/m<sup>3</sup>-yrs of asbestos while at that school. The low exposure of the school occupant is 0.00017 times the low exposure of the insulation worker, while the high exposure of the school occupant is 0.00016 times the high exposure of the insulation worker.

While the 1980 draft version of the EPA study proceeded to estimate the amount of disease that might be caused by such exposure, the final document contained no disease estimate. Both the methodology and the numbers were changed somewhat between the draft and the final version, so that it is not possible to produce a disease estimate directly from the final document. However, assuming a linear dose-response relationship for asbestos-related cancers, the data would imply that school occupants might experience about 0.00017 times the disease encountered by the insulation

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<sup>48</sup>U.S., Environmental Protection Agency, *Support Document for Final Rule*. . . , p. 72.

<sup>49</sup>Ibid., p. 91.

<sup>50</sup>Ibid., p. 94.

workers studied by Hammond, Selikoff, and Seidman.<sup>51</sup> The 1980 EPA report attributed to Hammond's study 716 excess cancer deaths among 12,051 workers exposed, or 59 deaths per thousand.<sup>52</sup> Multiplying this by 0.00017 yields 0.01 excess deaths per thousand school occupants. This equals 10 deaths per million occupants. While these numbers are subject to considerable uncertainty, they do not suggest a significant risk of asbestos-related disease for building occupants.

Julian Peto has performed an independent assessment of the risk of cancer for school occupants. He assumed that the U.S. insulation workers were exposed to an average of 30 f/cc for 20 years and extrapolated the risks to building occupants from the insulation worker experience, since the *type* of fibre exposure was the same. From his results, it can be calculated that the combined risk of death from asbestos-related lung cancer and mesothelioma for a student exposed for 6 years, from age 12 to age 18, to 0.001 f/cc would be 0.0063 per thousand exposed persons. A staff member exposed for 10 years from age 30 to 0.001 f/cc would face a nearly identical combined risk of 0.0061 per thousand exposed persons. Eighty percent or more of these deaths would occur after age 60.<sup>53</sup> These risks are equal to 6.3 or 6.1 deaths per million exposed persons.

The U.K. Advisory Committee on Asbestos also estimated possible health risks to building occupants. It posited a range of fibre exposures because of the difficulties of both measuring fibre levels in buildings and converting mass measurements to fibre counts. Using the Advisory Committee's median estimate, buildings expose occupants to 0.005 f/cc for 50 years; the cumulative dose is 0.25 fibres per cubic centimetre-years (f/cc-yrs); and the excess lung cancer mortality among building occupants might range from 5 to 170 deaths per million births.<sup>54</sup> The Advisory Committee concluded: "... unless contaminated buildings are very much commoner

<sup>51</sup>E. Cuyler Hammond, Irving J. Selikoff, and Herbert Seidman, "Asbestos Exposure, Cigarette Smoking and Death Rates," *Annals of the New York Academy of Sciences* 330 (14 December 1979): 473-490.

<sup>52</sup>U.S., Environmental Protection Agency, *Support Document for Proposed Rule on Friable Asbestos-Containing Materials in School Buildings: Health Effects and Magnitude of Exposure*, EPA 560/12-80-003 (Washington, D.C.: U.S. Environmental Protection Agency, October 1980), Table 17, p. 80.

<sup>53</sup>Julian Peto, "An Alternative Approach for the Risk Assessment of Asbestos in Schools," report to the U.S. Environmental Protection Agency, 6 April 1981, p. 14. (Mimeographed.) Mr. Peto has subsequently stated that the 30 f/cc exposure used in this paper was for illustrative purposes only, and that the Nicholson exposure estimate of 15 f/cc should be used. This change would raise Peto's risk estimates, perhaps to about 12 per million. Letter and attachments from Mr. Julian Peto, Imperial Cancer Research Fund, University of Oxford, Oxford, England to the Royal Commission on Asbestos, 21 September 1983.

<sup>54</sup>U.K., Advisory Committee on Asbestos, *Asbestos — Volume 1: Final Report of the Advisory Committee* (Simpson Report), William J. Simpson, Chairman (London: Her Majesty's Stationery Office, 1979), Table 22, p. 62.

than seems likely no appreciable mortality from lung cancer can be associated with any degree of contamination by chrysotile likely to be encountered in the U.K. in the ambient air or in buildings not under active construction or repair.”<sup>55</sup> However, the Advisory Committee emphasized the need for further information about asbestos levels in buildings.

The Ontario studies performed for this Commission reinforce the belief that the asbestos exposure of building occupants is low. In the previous section we conclude that the majority of exposures of building occupants would be below 0.001 f/cc with a few exposures as high as 0.01 f/cc, in buildings with friable asbestos insulation. Using the data from the risk assessment for exposed workers to evaluate risks to building occupants, if a contaminated building exposed the occupants to 0.001 f/cc more than the ambient air, the total mortality for a 10-year exposure might be approximately 0.001 times the mortality for a 1 f/cc exposure.

Let us now focus on the analysis of the study by Selikoff, Hammond, and Seidman, since this study examined insulation workers exposed to the types of fibres present in buildings.<sup>56</sup> In the Appendix to Chapter 7 of this Report, the Daniels and Roberts models, using the Selikoff data, yield mortality projections of 20 deaths per million persons exposed for 10 years, which is within the range found by the U.K. Advisory Committee. If we consider the regular occupant of a building area with the highest asbestos fibre levels, estimated in the preceding section as 0.01 f/cc, the risk of death based on the Selikoff data would be 200 per million such exposed persons. We believe that regular exposures of building occupants to fibre levels as high as 0.01 f/cc are unlikely. These estimates are uncertain both in the estimated exposures and in the estimated health effects of the exposures.

Studies of risks to building occupants have indicated a wide range of uncertainty as to the magnitude of those risks. In Chapter 7 we discuss the risks faced by workers, asking whether those risks are significant in comparison to other risks faced by workers. We now ask whether the risks faced by building occupants as a result of exposure to these asbestos fibre levels are significant in comparison to other risks faced by building occupants. In answering this question, we must identify other risks to be used as a basis for comparison.

Table 9.5 summarizes risks of death by various causes faced by Canadians, expressed in deaths per year per 100,000 population. The top part of the table shows fatality rates from accidents for Canadians in the year 1980

<sup>55</sup> Ibid., paragraph 132, p. 63.

<sup>56</sup> Irving J. Selikoff, E. Cuyler Hammond, and Herbert Seidman, “Mortality Experience of Insulation Workers in the United States and Canada, 1943–1976,” *Annals of the New York Academy of Sciences* 330 (14 December 1979): 91–116.

per 100,000 population per year. Motor vehicle traffic accidents caused 22.5 deaths per 100,000 population. The risk of death from accidental falls was 7.7 per 100,000. The risk of death from fire and from poisoning was 3.1 and 1.9 respectively per 100,000. The major diseases causing fatalities are shown in the bottom half of Table 9.5. Cardiovascular disease caused 337.2 deaths per 100,000 and cancer caused 165.3; while pneumonia caused only 19.7 and diabetes caused 12.0.

To compare the risk from asbestos exposure to these risks, a conversion must be made from the type of data presented by the U.K. Advisory Committee. The U.K. Advisory Committee data estimated the number of deaths per million births. To convert this to deaths per 100,000 population per year we need a population model. We will use a very simple model to produce order-of-magnitude figures for comparison purposes. Assume a state in which 1 million people are born every year, each of them living to age 70. With 1 million persons in each one-year age group, the number of deaths in one year is the same as the number of deaths experienced by a single group of 1 million persons over their 70-year lives. In this state, the population would be 70 million persons, which is  $700 \times 100,000$  persons. Thus, a death rate per million live births or per million exposed persons must be divided by 700 to produce deaths per 100,000 population. The U.K. Advisory Committee estimated 5 to 170 deaths per million live births, which would represent an average of 5 to 170 deaths caused by asbestos exposure per year in this hypothetical state. Dividing this death rate by 700 yields 0.007 to 0.24 deaths per 100,000 population. This is shown at the bottom of Table 9.5.

Above we estimate that there might be 20 deaths if 1 million persons were exposed to building insulation for 10 years at 0.001 f/cc. In our hypothetical state this would cause 20 deaths per year with a population of 70 million — or 0.029 deaths per year per 100,000 population. This is shown at the bottom of Table 9.5. The unlikely exposure to 0.01 f/cc implies a risk 10 times greater than that just calculated, or 0.29 deaths per 100,000.

The asbestos risks shown in Table 9.5 are, if anything, overstated in comparison to the risks of death from other causes. The asbestos risks assume that every member of the population is exposed to asbestos in buildings for either 10 years, when we use Daniels and Roberts, or 50 years, when we use the U.K. Advisory Committee. However, if only 10% of buildings contain asbestos, then on average only a small fraction of the population will be exposed to asbestos in buildings. It would therefore be incorrect to multiply the building risk represented in Table 9.5 by the ratio between the Canadian population and 100,000 in determining the total risk to all Canadians.

The person who works for 10 years in a building with 0.001 f/cc of asbestos might face a risk of death from that 10-year exposure of 20 per

**Table 9.5**  
**Risks of Death by Cause — 1980**  
**(Death rate per 100,000 population/year)**

<b>Cause of Fatality</b>	
<b>Accidents<sup>a</sup></b>	
Motor vehicles (traffic)	22.5
Falls	7.7
Drowning	3.4
Miscellaneous	2.9
Fire	3.1
Poisoning	1.9
Suffocation	2.2
Aircraft	0.7
Motor vehicles (non-traffic)	0.6
Firearms	0.3
<b>Disease<sup>b</sup></b>	
Cardiovascular diseases	337.2
Cancer	165.3
Pneumonia	19.7
Diabetes	12.0
<b>Asbestos Disease from Building Exposure</b>	
U.K. Advisory Committee on Asbestos (50 years) <sup>c</sup>	0.007-0.24
Royal Commission on Asbestos Estimate (10 years)	0.029

SOURCES: <sup>a</sup> Canada Safety Council, *Accident Fatalities, Canada 1980* (Ottawa: The Council, 1982), Table 2, p. 5.

<sup>b</sup> Ibid., Table 19, p. 24.

<sup>c</sup> Adapted from: U.K., Advisory Committee on Asbestos, *Asbestos — Volume 1: Final Report of the Advisory Committee* (London: Her Majesty's Stationery Office, 1979), Table 22, p. 62.

million. If the same person drove 10 miles to and from the building 250 days per year for 10 years, he would drive 25,000 miles. Since the number of fatalities per vehicle-mile travelled in Canada is approximately 45 per billion, the risk of death from commuting is 1,125 per million.<sup>57</sup> In short, the drive is over 50 times as dangerous as the building occupancy.

Are the risks of asbestos exposure to building occupants shown in Table 9.5 significant? Because they are orders of magnitude below the other risks faced by the general population, we conclude that these risks are not significant. While the health risk from asbestos in buildings may not be exactly zero, it is far below risks faced every day by Canadians in their ordinary lives. The risk to occupants from asbestos in buildings is a small fraction of the risks faced by workers exposed to asbestos under the 1 f/cc control limit for chrysotile. It is less than 1/50 as great as the risk of commuting by car to and from those buildings. In concluding that this risk is insignificant, we conclude that the risk does not present a public health problem. While asbestos has caused serious health problems for workers and may present a problem for building maintenance, renovation, construction, and demolition workers, we conclude that it does not pose a significant problem for the general occupants of a building, except in the three situations outlined in Section D of this chapter, namely: (i) the occupant is in the immediate vicinity of work that disturbs friable asbestos-containing insulation; (ii) the occupant is within the range of air circulation of work that disturbs friable asbestos-containing insulation; or (iii) significant quantities of friable asbestos-containing insulation have fallen onto building surfaces and are being disturbed.

While we have emphasized the uncertainties inherent in the risk assessment performed here, we can also indicate the boundaries of that uncertainty. First, the estimates of the fibre exposure of building occupants is subject to considerable uncertainty because of the absence of a standardized methodology for measuring fibre levels. Still, all the available exposure estimates indicate that few asbestos-containing buildings expose their occupants to as much as the equivalent of 0.01 f/cc of asbestos measured optically, and the best exposure estimate is less than the equivalent of 0.001 f/cc measured optically. This exposure is 100 to 1,000 times lower than the current workplace control limit for chrysotile. It is 1,000 to 10,000 times lower than the average exposure of insulation workers in the past. While the range of uncertainty in these exposures is large, all are at extremely low levels.

Second, there is not a well-established dose-response relationship between low exposures to asbestos fibres and asbestos-related diseases. We

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<sup>57</sup>Transport Canada, *1980 Canadian Motor Vehicle Traffic Accident Statistics*, TP 3322 (Ottawa: Transport Canada, 1980).

conclude in Chapter 5 that a linear relationship is both reasonable and prudent, in that it is unlikely that the true relationship would cause more disease than is predicted by a linear relationship.

What would it cost per person-year per fibre to reduce this exposure? Assume an office building that would be occupied by 1,000 workers for a period of 10 years. The average Toronto office building has 25 square metres of floor space for every worker.<sup>58</sup> Thus, a building housing 1,000 workers would occupy 25,000 square metres. We will assume, based on Pinchin, and given that prices for removal work have been dropping, that the cost of removing and replacing sprayed insulation is \$50 per square metre.<sup>59</sup>

If the building is occupied, the occupants must be moved out and back, which Pinchin estimated might cost \$15 to \$30 per square metre for office employees.<sup>60</sup> We will use \$20 per square metre. Alternate space must be found for the duration of the control work, and we will assume that this costs \$20 per square metre for one month. The sum of these removal, moving, and space costs is \$90 per square metre.

All of this cost must not be attributed to the immediate control programme, since we are recommending that the asbestos would have to be removed before the building could be demolished. (See Chapter 10.) The net cost of present control work is the cost of that work less the cost that would be incurred at demolition. Assume that the building would not be demolished for 20 years. Delaying asbestos removal until just prior to demolition will be less costly than if the building will be re-used, since less care must be exercised to avoid damaging the building and furnishings. We will assume that removal at demolition saves 25%, yielding a cost of \$37 per square metre. Since this cost would occur 20 years in the future, we must determine the present value of that amount today, since a lesser sum of money could be set aside today, which, with accumulated real interest, would amount to \$37 in real terms in 20 years. Using a 5% real discount rate, the present value today of \$37 in 20 years is \$11.53. The net cost of asbestos removal in an office building today could therefore be estimated at (\$90 - \$11.53) about \$80 per square metre. If we apply this cost to our hypothetical building, the cost of a removal project would be \$1.6 million. Dividing this control cost by an exposure reduction of 0.001 f/cc x 1,000 persons x 10 years yields a marginal cost of \$160,000 per person-year per f/cc. This calculation implies that a removal project could reduce fibre levels from 0.001 to 0, and hence overestimates the effectiveness of a

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<sup>58</sup>Telephone communication between Mr. Peter Tomlinson, Program Manager, Policy Section, Planning and Development Department, City of Toronto and Royal Commission on Asbestos Staff, 4 July 1983.

<sup>59</sup>Pinchin, *Asbestos in Buildings*, p. 8.9.

<sup>60</sup>*Ibid.*, p. 5.21.

removal project, since even buildings without asbestos-containing insulation have background levels of asbestos. If the actual fibre level is 0.01 f/cc, the cost is 1/10 as great per f/cc, or \$16,000 per person-year per f/cc.

In Chapter 6 we show that controlling worker exposures in brake manufacturing to an average exposure of 0.5 f/cc might cost \$2,700 per person-year per fibre. Thus, the cost of protecting building occupants at \$160,000 per person-year per fibre is enormously greater than the cost estimated for applying controls in the workplace, largely because the building exposures are insignificant.

We estimate above that an exposure of 0.001 f/cc for 10 years might create a risk of premature death of 0.02 per 1,000 exposed persons. Spending \$1.6 million to eliminate this risk implies an expenditure of \$80 million per possible life saved.

The evaluation of these costs of possible life saving may be compared with estimates of the costs of life saving that might result from other public programmes. If a limited amount of money is to be spent in protecting the health and longevity of Canadians, the greatest improvement in health and longevity will be achieved by spending that money where the cost per life saved is the lowest, so that the amount of life saving per dollar is greatest. Unfortunately, there are very few studies of the costs of life savings from public programmes in Canada. Byer, Bacchus, and Melcher analyzed the safety impact of 12 grade separation projects in Ontario from 1958 through 1976 in which level crossings between highways and railroads were replaced by bridges and underpasses. This study found that the highest cost among these 12 projects was \$16 million per estimated life saved, in 1979 Canadian dollars.<sup>61</sup> All values of the study, however, were quite sensitive to several of the assumptions.

In Chapter 7 we discuss a study that found that in the United States the median cost per life saved in various programmes was \$64,000 in motor vehicles and highways; \$102,000 in medical programmes; \$50,000 in consumer protection; \$2.6 million in environmental protection; and \$12.1 million in occupational health and safety programmes.<sup>62</sup> Not all the programmes analyzed have in fact been adopted by the U.S. government, but these figures probably give a rough estimate of the range of expenditures per life saved experienced in the United States. The estimated cost of possible life saving for building occupants from asbestos control programmes

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<sup>61</sup> Philip H. Byer, Aatur Bacchus, and Rowena Melcher, *Implying the Value of Life From Public Safety Investments*, Research Report, no. 64 (Toronto: University of Toronto-York University Joint Program in Transportation, March 1980), p. 24.

<sup>62</sup> John D. Graham and James W. Vaupel, "Value of a Life: What Difference Does it Make?" *Risk Analysis* 1:1 (March 1981): 91.

is far above the cost of life saving in other programmes. From the standpoint of occupants, asbestos control in buildings is uneconomic because the risk it removes for occupants is insignificant, and its costs are large.

Our conclusion that the occupants of buildings are generally not at risk from asbestos fibre exposure, and that asbestos control work may expose workers to substantially elevated asbestos fibre levels if not carefully performed, raises the question whether the programme to remove asbestos from all Ontario schools, involving an expenditure of provincial funds of over \$26 million to date, constituted an over-reaction, albeit well intentioned, to public concern vigorously expressed by parents alarmed by perceived health risks to their children. We appreciate that children may be somewhat more at risk from a given fibre exposure than are adults, as discussed in Chapter 5 above. The risk assessment models presented in the Appendix to Chapter 7 predict that children may be exposed to almost twice the risk faced by adults. Even acknowledging that the very young may be more susceptible to asbestos disease, the health risks to children remain insignificant because the level of exposure in asbestos-containing schools has in general been extremely low. The exceptions would be cases where asbestos material was actively disturbed, or where it fell onto building surfaces and was disturbed. It follows that, with these exceptions, the programme for removing asbestos from all asbestos-containing schools was not justified by the health risk posed to students. In some cases, the asbestos control work may have been justified in order to protect building renovation, maintenance, or custodial workers from exposure to asbestos if their work would have disturbed asbestos insulation. (See Chapter 10, Section D.) But neither the scale nor the pace of the school programme was warranted by the risk posed by most asbestos-containing schools to occupants or workers. If anything, the scale and pace of the programme significantly *increased* the risk to some workers directly engaged in control projects. Crash programmes invariably mean that inexperienced contractors and personnel will enter the field. A number of asbestos-control projects in schools were conducted in a manner which, according to the evidence before us, may have generated significant risk for the workers involved. (See Chapter 10, Section D.) There is no question, however, that the crash nature of the asbestos control programme in schools was occasioned by a climate of public apprehension; the actions of school boards and of the Ministry of Education, paralleled in other jurisdictions, show them to be responsive to public demand.

## **F. Recommendations for Occupant Protection**

We conclude that a universal programme of building inspection and control is not warranted to protect building occupants. As Pinchin has noted, this would be quite expensive. In addition, it is unlikely that such a programme could be performed at a high level of competence in a short

period of time, given the limited number of individuals who are adequately trained in this work and the length of time required to develop the necessary training and experience. Under the circumstances, only a selective approach to inspection and control is warranted.

In Section D of this chapter we conclude that building occupants are not subject to asbestos fibre exposure in excess of very small fractions of the recently adopted Ontario workplace control limits, except where: (i) the occupant is in the immediate vicinity of work that disturbs friable asbestos-containing insulation; (ii) the occupant is within the range of air circulation of work that disturbs friable asbestos-containing insulation; or (iii) significant quantities of friable asbestos-containing insulation have fallen onto building surfaces and are being disturbed. The recommendations we shall make in Chapter 10 for the protection of workers should also protect building occupants in the situations described in (i) and (ii) above. This leaves situation (iii). When significant quantities of insulation have fallen onto building surfaces and are being disturbed, this should be readily apparent to building occupants and to the person disturbing the fallen insulation. In buildings in which insulation was installed or replaced before 1974, the year when the use of asbestos in insulation ceased in Ontario, a person who observes such fallen insulation should have a right to have it tested at the expense of the building owner to determine whether it contains asbestos. If an occupant and the owner disagree on whether a "significant quantity" of insulation has fallen, the responsible Ministry could be called upon to assess the situation. We accordingly recommend that:

- 9.5 Legislation should be developed providing that, if significant quantities of friable insulation have fallen onto building surfaces and are being disturbed, the building owner must have the material tested to determine whether it contains asbestos. This requirement should apply only to insulation installed or replaced before 1974.*

We further recommend that:

- 9.6 Legislation should be developed providing that if the test mandated by the circumstances stipulated in Recommendation 9.5 shows that friable asbestos is present, the building owner must enclose, encapsulate, or remove the asbestos-containing material, following the work practices referred to in Recommendation 10.17.*

We consider that a programme of management and custodial control should be instituted as soon as the friable material is found to contain asbestos and should continue until the asbestos-containing material is removed: see Recommendation 10.6. As well, the results of testing under Recommendation 9.5 should be available to government inspectors, building workers, and building occupants: see Recommendation 10.3.

We have refrained from specifying which Ministry should be responsible for the implementation of Recommendations 9.5 and 9.6. The subject matter of these recommendations suggests a role for the Ministry of Health. However, the Ministry of Labour will have expertise in dealing with asbestos in buildings, because the main concerns raised by asbestos in buildings involve workers. We recommend that:

- 9.7 The Minister of Labour should communicate with the Minister of Health with a view to establishing responsibility with respect to Recommendations 9.5 and 9.6.*

## **G. Asbestos in Private Homes**

Friable asbestos has been used in private homes as insulation on cast iron hot water boilers for heating or for domestic hot water and as insulation on heating pipes. This asbestos is usually confined to the basement or to the furnace room in the basement. Any hot water or steam heating system that was installed or re-insulated before the mid-1970s might include asbestos insulation. It seems likely that a large proportion of cast iron hot water boilers currently in use in homes in Ontario would include some asbestos insulation.

The mere presence of such asbestos insulation does not pose a health risk. Only when the covering on the insulation is damaged so that dust can escape, *and* there is nearby activity such as that associated with a laundry, recreation room, or workshop, is there a possibility of asbestos fibre exposure for the building occupants. If the boiler is in a separate room that is never used by building occupants, there should be no risk. Because asbestos in private homes is unlikely to present health risks to building occupants, because the owner is usually the occupant, and because of the difficulties of enforcing regulations upon the large number of private homes in Ontario, it is not appropriate that the duties of Recommendations 9.5 and 9.6 above be applied to such homes. Accordingly, we recommend that:

- 9.8 Owners of private homes should be exempt from the duties set out in Recommendations 9.5 and 9.6 above.*

The risk, if any, presented by asbestos insulation in private homes is not to the building occupant, but to workers who may disturb that asbestos in performing maintenance work on the boilers or pipes. We therefore recommend that:

- 9.9 The Ministry of Labour should communicate with workers who replace and maintain domestic space-heating boilers to inform them of the risks of working with asbestos and of the appropriate safety precautions for such work.*

While asbestos-containing pipe or boiler insulation will be found in many homes, in most cases there will be no risk to building occupants. When a risk to building occupants or workers is suspected, because the insulation is damaged and there is activity nearby, tests should be performed to determine whether or not asbestos is present. If it is present, it can be controlled in place or, if necessary, removed. Because removal necessarily disturbs the asbestos and presents some risk of exposure both to the removal worker and to the occupants of the house, removal is not recommended unless a definite risk is identified. To control the asbestos in place, the homeowner should avoid unnecessary activity which might disturb the asbestos. In addition, workers whose work might disturb the asbestos should be informed that asbestos is present, so that safe work practices can be employed. We recommend that:

*9.10 The Ministry of Labour should prepare a brief flyer describing the possible locations of asbestos on pipes and boilers in the home, the proper method of sampling suspect material, and any appropriate precautions should asbestos be found to be present.*

This flyer could be supplied to municipalities throughout the province, to be distributed to ratepayers with their property tax bills.

Other asbestos building products which might be found in homes include floor tiles and asbestos-cement sheet. These are discussed in Chapter 10 and present no risk to the occupant of the house in ordinary use. We have investigated the possibility that loose asbestos may have been used as attic insulation in private homes. We find no evidence that asbestos was so used on a commercial scale, although a few homes may contain such insulation, probably installed by the homeowner himself. Apparently asbestos has always been more expensive than competing loose insulation of equivalent insulation capability, so that there was no reason to use asbestos in attics.



## **Chapter 10    Protecting Workers from Asbestos in Buildings**

### **A. Introduction**

In Chapter 9 we conclude that the presence of friable asbestos in buildings does not present a health hazard to building occupants except in special circumstances where work disturbs friable asbestos-containing insulation or where substantial quantities of friable asbestos-containing insulation have fallen onto building surfaces and are being disturbed. In contrast, the same data that show the relative insignificance of most building occupant exposures also show that workers who disturb asbestos-containing insulation may be exposed to fibre levels at or above Ontario control limits. The removal of asbestos-containing insulation generally causes very high dust levels. Enclosing or encapsulating asbestos-containing insulation may cause high dust levels; working above a suspended ceiling which encloses sprayed asbestos may cause high dust levels; and work on a surface covered with asbestos-containing insulation may cause high dust levels. As well, working with new building products which contain asbestos causes elevated fibre levels, not for building occupants, but for the tradesmen who work on the building itself.

This chapter explores the magnitude of the problem of worker exposure to asbestos in buildings and the steps necessary to protect the health of the workers concerned. We consider that these steps should be incorporated in a regulatory instrument which is separate and distinct from the Regulation Respecting Asbestos that was promulgated in 1982. The Regulation Respecting Asbestos was drafted with the manufacturing and mining sectors in mind, imposing numerical asbestos control limits and relying on air monitoring for its enforcement. It does not apply to work on construction projects. The Ministry of Labour intends to regulate asbestos exposure on such projects, which include activities related to removal and demolition, by framing a separate regulation under the *Occupational Health and Safety*

*Act*. It published an exposure draft of this regulation, entitled Proposed Regulation Respecting Asbestos on Construction Projects and Related Codes (PRRACP), in *The Ontario Gazette* in August 1982 and presented a revised version at a public meeting in January 1983.<sup>1</sup>

The PRRACP relies on regulation by procedure rather than on control limits. However, the scope of the PRRACP is limited to what is defined in section 1, paragraph 23 of the *Occupational Health and Safety Act* as "construction," which includes erection, alteration, repair, dismantling, demolition, and structural maintenance. We endorse regulation by procedure on construction projects so defined, but consider that this approach is likewise appropriate to activities that involve building maintenance and custodial work. Regulation by procedure specifies procedures to protect worker health and safety and provides an immediate means of deciding whether a given work practice is safe.

Building maintenance and custodial work, like construction projects as defined in the Act, cannot be regulated appropriately through the fixed workplace approach of imposing control limits enforced by air monitoring. As we observed in Chapter 9, Section C, the only standardized workplace measuring technique, phase contrast microscopy, cannot distinguish asbestos dust from non-asbestos dust. Since most building work can be expected to raise significant amounts of non-asbestos dust, it is not practicable to regulate this work through reliance on air monitoring. Furthermore, fibre levels can vary tremendously in building or construction work, from time to time and from place to place on the same job. This is because the nature of the work and the material being worked on vary as the job progresses. Even if air monitoring took place every hour of every day, the laboratory analysis might not be completed for a few days, often too late to be useful if the work that caused high exposures has been replaced with some other work.

We, therefore, conclude that regulation by procedure, because of its immediate focus on safe work practices, provides the appropriate means of regulating asbestos exposures that might be encountered in building-related work activities, whether these be on construction projects or in association with building maintenance and custodial work. It follows that the scope of regulation by procedure envisaged by the Ministry's PRRACP should be broadened to extend beyond construction projects to maintenance and custodial work in buildings. Accordingly, the Ministry of Labour should

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<sup>1</sup> Ontario, Ministry of Labour, Occupational Health and Safety Division, "Proposed Regulation Respecting Asbestos on Construction Projects and Related Codes," presented at a Public Meeting, 17 January 1983, Toronto. (Mimeographed.) This "Proposed Regulation. . ." is a revision of the "Notice of Proposed Regulation: Designated Substance — Asbestos on Construction Projects," *The Ontario Gazette*, vol. 115-33, Saturday, 14 August 1982, pp. 3194-3197.

proceed to frame a regulation pursuant to the *Occupational Health and Safety Act* on asbestos on construction projects and in buildings and should amend the existing Regulation Respecting Asbestos so as to specify that its terms do not apply to work activities covered by the new regulation. We therefore recommend that:

***10.1 The Ministry of Labour should frame a regulation under the Occupational Health and Safety Act respecting asbestos on construction projects and in buildings which includes building custodial and maintenance work. The Ministry should amend the existing Regulation Respecting Asbestos so as to specify that its terms do not apply to work activities encompassed by the new regulation.***

How widespread is the exposure of building workers to elevated asbestos fibre levels? Not every building in Ontario contains friable asbestos. For the most part, asbestos-containing insulation was not applied in Ontario buildings after 1973. Sprayed asbestos-containing insulation is extremely rare in residential buildings of any kind and is most common in non-residential, multi-storey buildings. We estimate that less than 10% of non-residential, multi-storey buildings in Ontario contain sprayed asbestos-containing insulation and less than 20% contain extensive asbestos-containing pipe and boiler insulation.

Even in those buildings which contain friable asbestos insulation, the possibility of a health risk for workers is largely limited to situations where work will disturb this asbestos. As in Chapter 9 we conclude that there is no justification for a universal programme of building inspection to discover the presence of asbestos for the protection of occupants, so here we will conclude that such universal building inspection is not required to protect workers. Even less is a universal programme of asbestos removal called for. What is generally necessary is to test or inspect for the presence of asbestos prior to work that may disturb friable fibrous material. Control work, other than the basic management required as soon as friable asbestos is discovered in a building, becomes necessary only when the presence of asbestos is proved and the work activity to be performed on or near it suggests that there will be a hazard to building workers. Therefore, most asbestos control work will be performed prior to the demolition, major renovation, or major maintenance of a building. When minor renovation or maintenance is contemplated, the application of safe work practices will usually be sufficient to protect workers from excessive exposures.

Identifying situations that may present health risks to workers requires imposing some duties on building owners, contractors, and workers themselves. Building owners, contractors, and workers must be instructed in identifying possibly hazardous situations and in safe practices to be used in those situations. Qualifications must be established for those who inspect

buildings for asbestos and for those who supervise and inspect asbestos control work.

The overall thrust of the recommendations in this chapter is to ensure that asbestos-containing material is identified before it is disturbed, and that adequate protective measures are taken when it is disturbed to ensure that workers are not exposed to potentially significant fibre levels. The remaining sections of this chapter will describe an approach to inspecting buildings for asbestos hazards, corrective actions that may be taken to control asbestos, and safe practices for working with asbestos in buildings.

In Chapter 7 of this Report we identify the appropriate control limits for worker exposure to asbestos in fixed workplaces, and in Chapter 8 we devote considerable effort to examining the problems of implementing this control limit. Concern with asbestos in buildings and on construction projects is more recent than concern with asbestos in fixed workplaces. There is much less experience with regulating asbestos in buildings than with regulating asbestos in fixed workplaces and therefore less of a foundation upon which this Commission might build recommendations for effective implementation. We have attempted to be as realistic as possible in our recommendations, recognizing the helpful input received from written submissions and testimony regarding the experience of workers with asbestos on construction projects in this province. We recognize, however, that our treatment of implementation is, for the reasons just stated, less complete in the area of asbestos in buildings than of asbestos in fixed workplaces. We urge that as the Ministry of Labour, workers, and industry develop experience in this regulatory area, careful note be taken of the problems of implementation so that appropriate adjustments may be made.

## **B. Inspecting Buildings for Asbestos**

### **B.1 Current Programmes of Inspection**

In the United Kingdom, the Advisory Committee on Asbestos concluded that the risk to building occupants from asbestos fibre exposure was not sufficient to warrant either removal of all asbestos from existing buildings or a universal programme of asbestos identification in buildings.<sup>2</sup> A large number of building owners in the United Kingdom, in both the private and public sectors, have nonetheless undertaken complete asbestos surveys of their buildings even though this is not required by legislation.<sup>3</sup>

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<sup>2</sup>U.K., Advisory Committee on Asbestos, *Asbestos — Volume 1: Final Report of the Advisory Committee* (Simpson Report), William J. Simpson, Chairman (London: Her Majesty's Stationery Office, 1979), paragraph 248, p. 91.

<sup>3</sup>Donald J. Pinchin, *Asbestos in Buildings*, Royal Commission on Asbestos Study Series, no. 8 (Toronto: Royal Commission on Asbestos, 1982), p. 2.2.

In the United States, there has been no mandatory universal programme for inspecting private or public buildings for asbestos. However, in May 1982, the U.S. Environmental Protection Agency (EPA) published in the *Federal Register* a requirement that public, elementary, and secondary schools be inspected for friable asbestos-containing materials. School officials must maintain records of the inspection results, notify employees of the locations of friable asbestos materials, and provide employees with instructions on reducing exposure to asbestos.<sup>4</sup> The rule does not require that any particular control action be taken. In general, building inspection for asbestos in the United States is concentrated in school buildings. Two types of inspection programmes have been carried out in Ontario. In the first type, an organization establishes a programme to inspect all buildings within its jurisdiction that may contain asbestos. In the second type, buildings are inspected only when concern is expressed over particular problems in particular buildings.<sup>5</sup> In his study for this Commission, Dr. Donald J. Pinchin described examples of current inspection programmes in Ontario.<sup>6</sup> The Ministry of Education, which has jurisdiction with respect to schools, has supervised a comprehensive inspection programme. Public Works Canada, the National Capital Commission, and the City of Windsor Utilities Commission have also performed comprehensive inspections of buildings within their purview. On the other hand, the Ontario Ministry of Government Services has only inspected buildings in response to complaints.

All federal departments have completed inspection programmes and are carrying out corrective work.<sup>7</sup> In addition, a number of building owners in the private sector have begun or completed their own inspection programmes. It would seem that most inspection programmes in the private sector follow the approach, adopted by the Ontario Ministry of Government Services, of inspecting buildings only in response to particular concerns.<sup>8</sup>

The comprehensive schools inspection programmes commenced in the summer of 1979 under the direction of the Ministry of Education.<sup>9</sup> The results of the inspection of schools in Ontario, as of March 10, 1982, were that 80.18% of schools contained no asbestos, 9.35% contained exposed sprayed asbestos, less than 0.4% contained sprayed asbestos in an air

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<sup>4</sup>U.S., Environmental Protection Agency, "Asbestos; Friable Asbestos-Containing Materials in Schools; Identification and Notification," *Federal Register*, vol. 47, no. 103, 27 May 1982, pp. 23360-23389.

<sup>5</sup>Pinchin, *Asbestos in Buildings*, p. 2.23.

<sup>6</sup>Ibid., chap. 2.

<sup>7</sup>Ibid., p. 2.19.

<sup>8</sup>Ibid., p. 2.23.

<sup>9</sup>Advisory Task Force on Asbestos in Schools, *Report (A Practical Document)* (Toronto: Metropolitan Toronto School Board, May 1980), Appendix A.

plenum, and 10.07% contained other friable asbestos.<sup>10</sup> School boards were asked to take corrective action to eliminate any friable asbestos hazards discovered as a result of the inspections.<sup>11</sup> Options included encapsulation, enclosure, removal, and management and custodial control.<sup>12</sup> Financial assistance to school boards for asbestos control programmes had cost the province approximately \$26 million as of February 1983. Further expenditures amounting to \$15 million were anticipated at that time.<sup>13</sup>

The Ontario Ministry of Government Services manages approximately 9,300 buildings in Ontario. Rather than undertake a comprehensive inspection programme, the Ministry of Government Services conducts visual inspections, bulk sampling, and air sampling in response to specific enquiries or concerns. Pinchin reported that as of March 12, 1982, 68 buildings had been inspected for asbestos.<sup>14</sup> Thirty-seven of the 68 buildings were found to contain friable asbestos products, 12 buildings were found to contain no asbestos, and 19 of the buildings were still under investigation. The Ministry of Government Services has responded to the discovery of sprayed asbestos-containing insulation in its buildings with guidelines on management and custodial control. Also, friable pipe insulation is repaired and recovered in accordance with Ministry of Government Services guidelines. These measures have been relatively low cost. It is recognized that any major repair, renovation, or demolition which would disturb friable asbestos-containing material should involve special precautions.<sup>15</sup>

At the federal level of government, Public Works Canada owns and manages almost 13,000 buildings across Canada. These buildings have been reviewed, and 3,700 of them have been physically inspected for sprayed friable asbestos. Only 34 buildings were found to contain sprayed asbestos-containing material. The control options chosen for these buildings were: removal (22 buildings); encapsulation (1 building); enclosure (3 buildings); and management and custodial control (8 buildings). It was estimated that correctional work for these 34 buildings would cost \$30.4 million.<sup>16</sup> One can summarize the Ontario experience of Public Works Canada by noting

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<sup>10</sup>Letter from Mr. Stanley Orlowski, Associate Chief Architect, Grants Policy Branch, Ontario Ministry of Education to the Royal Commission on Asbestos, 23 February 1983.

<sup>11</sup>Ontario, Royal Commission on Asbestos, *Proceedings of The Royal Commission on Asbestos, First Public Meeting, Friday, October 31, 1980*, reported by Elizabeth J. Hiscott (Toronto: Royal Commission on Asbestos, 1980), p. 33.

<sup>12</sup>*Ibid.*, p. 32; and G. Bruce Doern, Michael Prince, and Garth McNaughton, *Living with Contradictions: Health and Safety Regulation and Implementation in Ontario*, Royal Commission on Asbestos Study Series, no. 5 (Toronto: Royal Commission on Asbestos, 1982), pp. 4.15–4.16.

<sup>13</sup>Letter from Mr. Stanley Orlowski to the Royal Commission on Asbestos, 23 February 1983.

<sup>14</sup>Pinchin, *Asbestos in Buildings*, p. 2.20.

<sup>15</sup>*Ibid.*, p. 2.21.

<sup>16</sup>*Ibid.*, p. 2.17.

that 23 of its Ontario buildings contained sprayed friable asbestos-containing materials, representing 2.3% of the Public Works Canada buildings in this province. Public Works Canada also leases a number of buildings for various federal government departments; 4.4% of the Ontario buildings leased by Public Works Canada were found to contain sprayed friable asbestos-containing materials.

In Chapter 9 we conclude that the potential exposure of building occupants to elevated asbestos fibre levels does not warrant a universal programme of building inspection. Rather, we recommend that if substantial quantities of friable insulation have fallen onto building surfaces and are being disturbed, the building owner should have the material tested to determine whether it contains asbestos.<sup>17</sup> This recommendation is responsive to situations of potential hazard. In the same vein, we recognize that building workers, including custodial, maintenance, renovation, and demolition workers, may be exposed to substantially elevated asbestos fibre levels if their work disturbs friable asbestos in buildings. Accordingly, inspections and testings should occur in the context of work activities which give rise to potential hazards.

We anticipate that inspection in response to potential hazards will allow for timely corrective action, so that potential hazards do not become actual hazards. Such inspection, being selective, can be conducted with due care by qualified experts. In contrast, a crash programme of universal inspection of Ontario buildings could not be conducted at an adequate level of competence because there are few qualified experts in building inspection and because competent analytical laboratories in Ontario do not have the capacity to analyze the bulk samples from a crash programme.

## B.2 Visual Inspection

In Chapter 9 we observe that during normal activity, airborne asbestos fibre levels even in “problem” buildings are quite low. However, as Pinchin has pointed out, these readings do not eliminate the possibility of risk in such buildings, since maintenance, renovation, or demolition activities can generate substantial fibre levels for the workers engaged in those activities.<sup>18</sup> As well, damaged asbestos-containing materials can become dislodged and can then be stirred up by cleaning activity or normal building use, generating elevated fibre levels even for building occupants. Accordingly, Pinchin concluded that airborne fibre levels are not an appropriate basis for determining whether to take corrective action in buildings. Rather, the condition of the material and the probability of its being disturbed during mainte-

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<sup>17</sup> See Recommendation 9.5.

<sup>18</sup> Pinchin, *Asbestos in Buildings*, pp. 6.15–6.16.

nance, renovation, or demolition — or by building occupants — are the important factors.<sup>19</sup>

We consider that while air sampling with transmission electron microscope analysis (TEM) can detect elevated fibre levels in a building at the time of air sampling, it does not in general provide a reliable basis for deciding on an appropriate control programme. The main concern raised by friable asbestos-containing material in buildings is the potential elevation of fibre levels during maintenance, renovation, or demolition, which will primarily affect the workers on those jobs. Thus, building inspection should focus on factors which indicate that potential. Building inspection should accordingly consist of a visual inspection and laboratory analysis of bulk samples of friable material thought to contain asbestos.

Factors noted in visual inspections have generally included:

- (i) Condition of material: If material is deteriorating, coming loose, or if pieces are falling off, the possibility of fibre release is increased.
- (ii) Water damage: If water is leaking onto the material, it can cause rapid deterioration leading to fibre release.
- (iii) Exposed surface area: The greater the exposed surface area of the material, the greater the likelihood that any released fibres will reach people working nearby. While a suspended ceiling may cause material to be classified as non-exposed, it should be appreciated that maintenance workers above the suspended ceiling are not protected by the enclosure.
- (iv) Accessibility: If the material can be reached by workers or occupants, it is potentially subject to accidental or intentional damage which may release fibres.
- (v) Activity and movement: Air movement or building vibration can cause fibre release, while the movement of people or vehicles on the floor can stir up fibres that have settled. Cleaning by dry methods causes particularly high airborne fibre levels.
- (vi) Air plenum or direct air stream: If friable material is enclosed within an air plenum, any fibre release which may occur is more likely to be distributed throughout the building than if the material is not enclosed within the ventilating system.

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<sup>19</sup>Ibid., p. 6.16.

(vii) Friability: The more friable the material, the greater the potential for asbestos fibre release. Some wet-applied asbestos-containing materials can be quite hard and release very few fibres under most conditions.

(viii) Asbestos content: The higher the asbestos content in the material, the greater the number of asbestos fibres released under any given condition.

A Task Force of the Council of Safety Associations of Ontario has set out procedures for determining the presence of asbestos hazards. These can be used in investigating the factors listed above.<sup>20</sup>

It is difficult to combine subjective evaluations of the above factors into a single rating of the degree of risk or hazard presented by a particular building. Nonetheless, several attempts have been made to create a single hazard rating, or index, combining all of the factors, for sprayed materials only. These indices have generally been intended to identify potential fibre release so as to permit the ranking of buildings according to this potential. This is achieved by providing a mathematical equation, or algorithm, requiring that each factor be given a numerical rating.

The U.S. EPA published a draft index in 1979 which correlated poorly with measurements of asbestos fibres in the air and which is not likely to be issued in final form.<sup>21</sup> The Ferris Index has been adopted in a modified form by the Toronto Board of Education.<sup>22</sup> The U.S. Navy Risk Evaluation Index considers the number of persons exposed to a particular condition as a factor in assessing a hazard. These indices are discussed by Pinchin.<sup>23</sup> Other than the U.S. EPA index, they do not specify appropriate actions or ranges of actions for any given index level.

Pinchin studied a number of buildings which were inspected and rated according to the various hazard indices and were, at the same time, tested for asbestos content in the air.<sup>24</sup> The purpose of the study was to determine how well the exposure indices could predict or identify buildings in which fibre levels were elevated or, alternatively, how accurately air monitoring could be used to identify buildings which the indices determined were hazardous. In all cases, the asbestos fibre levels were extremely low [less than 11 nanograms per cubic metre (ng/m<sup>3</sup>)]. Yet some buildings exhibited

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<sup>20</sup>Task Force of the Council of Safety Associations, *Asbestos: Evaluation and Control of Insulation and Pipe Lagging*, Asbestos in the Workplace — a series of practical guidebooks, no. 8 (Toronto: Council of Safety Associations of Ontario, 1982).

<sup>21</sup>Pinchin, *Asbestos in Buildings*, p. 6.2.

<sup>22</sup>*Ibid.*, p. 1.23. For a discussion of the Ferris Index, see, for example, Karen F. Irving, Rexford G. Alexander, and Harold Bavley, "Asbestos Exposures in Massachusetts Public Schools," *American Industrial Hygiene Association Journal* 41:4 (April 1980): 270-276.

<sup>23</sup>Pinchin, *Asbestos in Buildings*, p. 1.23.

<sup>24</sup>*Ibid.*, pp. 6.6-6.16.

conditions which posed the possibility of significant fibre release. Pinchin concluded that there is no useful correlation between the hazard indices and asbestos fibre concentrations measured by him in building air during normal use. This does not, however, rule out the possibility that reference to the hazard indices could identify a building in which fibre levels would be elevated by work activity.

The inspection programme which we will recommend below is responsive to particular types of work activity. (See Recommendation 10.2.) It does not involve reliance on the hazard indices, in the sense that buildings need not be assigned a hazard level rating. Our focus is rather on the detection of friable asbestos before work which might disturb it commences, in order that precautionary steps may be taken. The elements taken into account by the hazard indices, however, remain relevant to the performance of visual inspections.

### B.3 Cost of Inspection

The cost of inspecting buildings for asbestos depends on a number of factors discussed by Pinchin.<sup>25</sup> He suggested that a preliminary inspection should be performed to determine whether there is a possibility of asbestos material being present, with a more detailed follow-up inspection to be undertaken only in buildings where this presence seems likely. The preliminary inspection is considerably less costly than a detailed inspection and can greatly reduce overall costs. Pinchin estimated the cost in 1980 Canadian dollars of a preliminary walk-through inspection at about \$0.04 per square metre of floor space, while a secondary survey, sufficiently detailed to provide working drawings for contracts for asbestos correction, might cost an average of \$0.10 per square metre of floor space.

Table 10.1 shows a summary of inspection costs experienced by Canadian and Ontario government bodies. In most cases the cost per building averaged over all buildings is far less than the cost per building of those buildings that were subjected to a detailed physical inspection. Thus, the Toronto Board of Education and the Rural School Board experienced similar costs in the buildings physically inspected, but the Toronto Board had a much lower cost average over all buildings because a number of buildings did not require a careful secondary inspection. The high cost per square metre of inspecting buildings experienced by the Windsor Utilities Commission is due in part to the small physical size of each building: the cost per square metre of inspecting a building declines as the total floor space in the building increases. In addition, a building owner learns from experience in

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<sup>25</sup>Ibid., chap. 4.

Table 10.1  
Summary of Inspection Costs  
(1980 \$ Canadian)

Organization	Persons Performing Inspection	Cost Per Building (\$)		Cost Per Square Metre (\$/m <sup>2</sup> )	
		Averaged Over All Buildings	Averaged Over Buildings Physically Inspected	Averaged Over All Buildings	Averaged Over Buildings Physically Inspected
Public Works Canada	Existing staff	54.20	152.57	0.07	—
National Capital Commission	Existing staff	131.70	131.70	—	—
Toronto Board of Education	Existing staff and Consultant	169.79	536.55	0.02	—
A Rural School Board	Consultant	597.57	597.57	0.10	0.10
Windsor Utilities Commission	Consultant	175.00	175.00	0.34	0.34

SOURCE: Donald J. Pinchin, *Asbestos in Buildings*, Royal Commission on Asbestos Study Series, no. 8 (Toronto: Royal Commission on Asbestos, 1982), Table IV, p. 4.12.

inspecting buildings, so that the cost per square metre declines with the total number of buildings inspected.

## B.4 When to Inspect

Friable asbestos-containing materials in buildings may be hazardous to workers who deal with those materials in maintenance, renovation, or demolition work. Such work may also present some hazard to building occupants. Inspection or testing should accordingly be undertaken to determine whether friable asbestos is present prior to doing work on any building in which insulation was installed or replaced prior to 1974.<sup>26</sup> We therefore recommend that:

### *10.2 The regulation under the Occupational Health and Safety Act on asbestos on construction projects and in buildings should require as follows:*

- (i) Before the demolition or renovation of any building the characteristics of which raise the possibility that it might contain friable asbestos, the building owner must cause the building or relevant part of the building to be inspected to determine whether friable asbestos-containing materials are present. If friable asbestos-containing materials are present, Recommendation 10.11 should be followed in the case of demolition, and Recommendations 10.14 and 10.17 should be followed in the case of renovation.*
- (ii) Before performing maintenance or custodial work which would disturb friable fibrous material in any building the characteristics of which raise the possibility that it might contain asbestos, the building owner must cause the material to be disturbed to be tested for asbestos content. If the material is found to contain asbestos, the employer must cause work practices to be adopted which ensure the health and safety of the maintenance or custodial workers, as outlined in Recommendations 10.6, 10.14, and 10.17. Alternatively, the maintenance or custodial work may proceed without the suspect material being tested, provided that the work practices followed would be safe in the event that the material did contain asbestos.*
- (iii) The requirements of (i) and (ii) above should apply only to buildings in which insulation was installed or replaced before 1974.*

A question arises as to who should be responsible for identifying asbestos-containing insulation in buildings and for ensuring that safe work

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<sup>26</sup>The use of asbestos-containing insulation by and large ceased by 1974. See Chapter 9 of this Report.

practices are pursued. Under the internal responsibility system of the *Occupational Health and Safety Act*, the worker and employer are jointly responsible for providing safe working conditions. Of equal importance, the building owner is in general responsible for the building and its condition. We believe that the building owner should be jointly responsible with the employer for responding to possible asbestos hazards which may be encountered in the course of work in the building. Accordingly, we have, in the above recommendation, outlined the duties of a building owner to inspect and to test. Similarly, owners should make the results of required inspections and tests known to interested persons. We accordingly recommend that:

**10.3** *The regulation under the Occupational Health and Safety Act on asbestos on construction projects and in buildings should require that in any case where a building is required by law to be inspected or tested for asbestos, the building owner must cause the results of the inspection or testing to be recorded as follows:*

- (i) *in a public place to be designated by the Ministry of Labour;*
- (ii) *in a document maintained on the building premises, under the care of the building owner or his representative. This document should be required to be shown on request to any government inspector, any building occupant, or any worker who is in the building for the purpose of exercising his trade and who might be exposed to friable fibrous material; and*
- (iii) *by placing signs or labels, in areas where asbestos material has been discovered, that clearly indicate the presence of asbestos and warn that the material should not be disturbed without using appropriate precautions.*

## **B.5 Laboratory Procedures for Analysis of Bulk Samples**

Two studies conducted for this Commission discussed several cases in the schools programme where confusion arose as to whether or not asbestos was present in a building, specifically as a result of conflicting laboratory reports on bulk materials sent for analysis.<sup>27</sup> This problem demonstrates the importance of the application of careful laboratory procedures for analyzing the material. We therefore recommend that:

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<sup>27</sup>G. Bruce Doern, *The Politics of Risk: The Identification of Toxic and Other Hazardous Substances in Canada*, Royal Commission on Asbestos Study Series, no. 4 (Toronto: Royal Commission on Asbestos, 1982), chap. 2; and Doern, Prince, and McNaughton, *Living with Contradictions: Health and Safety Regulation and Implementation in Ontario*, chap. 4.

*10.4 The regulation under the Occupational Health and Safety Act on asbestos on construction projects and in buildings should provide for standardized laboratory procedures to be followed for analysis of bulk material taken from buildings. These procedures should be reviewed from time to time so as to keep up with developing technology.*

## B.6 Qualifications of Inspectors

Pinchin has noted that “. . . inspections may miss a large percentage of the friable asbestos, unless the inspectors have been adequately trained.”<sup>28</sup> In some cases, Pinchin pointed out, improper inspection has led to a failure to detect substantial amounts of asbestos-containing material. Pinchin also documented an instance where inadequate inspection skills almost led to removal of material which was finally determined not to contain asbestos at all.

Pinchin has indicated that given a technical background and some experience in construction, a one- or two-day course would provide sufficient training for building inspection. Such a course would include a description of the uses of asbestos in buildings; a discussion of friability; an introduction to the hazard evaluation index; and techniques for performing inspections, including techniques for taking bulk samples. While the special training required for these inspection functions is not very extensive, it can be readily appreciated that, absent such training, there is a significant risk of missing asbestos in a building. Victims of such errors, moreover, would most often be workers who are not in a position to select or direct the inspector.

Generally, it will be the building owner who hires a building inspector. Given the various reasons which might impel an owner to carry out an inspection, it is not necessarily the case that a building owner would want a thoroughgoing inspection; a more immediate goal might in some cases be to assuage worker or occupant concerns. Alternatively, pursuant to Recommendation 10.2, the objective might be to fulfill a legal obligation to inspect before commencing work on the building. When one considers the expense which can be involved in an asbestos control programme, it becomes apparent that building owners may have a significant interest in not finding asbestos-related risks. Accordingly, the building owner's choice of inspectors should be restricted to suitably qualified persons. Such persons should be under an obligation to carry out inspections competently and honestly.

We note that section 41(1) of the *Occupational Health and Safety Act* provides for the making of such regulations under that Act as are advisable

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<sup>28</sup> Pinchin, *Asbestos in Buildings*, p. 4.2.

for the health and safety of persons in or about a workplace. Since the quality of inspections for asbestos in buildings would have a direct impact on the health and safety of building workers, it may be possible to pass a regulation pursuant to section 41(1) providing that inspections for asbestos in buildings which are required by law are to be carried out only by suitably qualified persons. In the event that such a provision is believed to be beyond the ambit of section 41(1), an enabling amendment to the *Occupational Health and Safety Act* would be required. We accordingly recommend that:

*10.5 The Ministry of Labour should take steps to institute a register of individuals certified as competent to inspect buildings for asbestos. Certificates of competence should be awarded by the Ministry of Labour upon an applicant's having satisfactorily completed an approved examination. Incompetence or dishonest practices should result in the certificate being revoked. Only individuals named in the register should be permitted to undertake inspections for asbestos in buildings which are required by law.*

## C. Corrective Actions

There are four primary procedures for controlling asbestos-containing material in a building. These are:

- (i) Management and Custodial Control<sup>29</sup> (Deferred Action): Asbestos-containing material is left as is in the building, and procedures are established to reduce or minimize any potential fibre release.
- (ii) Enclosure: Asbestos-containing material is enclosed behind a solid barrier.
- (iii) Encapsulation: Asbestos-containing material is coated with a bonding agent or sealer.
- (iv) Removal: Asbestos-containing material is removed and disposed of.

### C.1 Cost of Control Procedures

Pinchin has presented extensive data on the cost of controlling asbestos in buildings, referring primarily to the cost of asbestos removal.<sup>30</sup> He

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<sup>29</sup>The term "management and custodial control" is from Pinchin, *Asbestos in Buildings*, p. 1.29.

<sup>30</sup>*Ibid.*, chap. 5.

reported that the U.S. EPA determined average costs, in 1980 U.S. dollars, as follows: removal, disposal, and re-insulation — \$73.82 per square metre; encapsulation and marking — \$24.64 per square metre; and enclosure and marking — \$44.23 per square metre. Behind these averages lies a wide range of costs for each of the three control options.

In Ontario, the cost of removal of sprayed asbestos insulation ranges from a low of \$13.72 in 1980 Canadian dollars to a high of \$233.78 per square metre, with an average cost range of \$50 to \$100 per square metre.<sup>31</sup> Prices in 1982 were at the low end of this range.<sup>32</sup> The cost of removing pipe and boiler insulation has been estimated at about \$150 per square metre, based on a sample of only two projects. It is not possible to calculate an average cost of encapsulation or enclosure from the Ontario data, but the ratio found in the United States probably applies: 1.0 to 1.8 to 3.0 is the U.S. ratio among the costs of encapsulation, enclosure, and removal.

What would it cost to remove all sprayed asbestos from Ontario buildings? This question is difficult to answer because only a small fraction of all buildings in Ontario have been inspected for asbestos-containing materials, and because there is no single list or inventory of all buildings existing in the province. Based on the inspections that have been performed on schools and government buildings in the province, Pinchin concluded that somewhere between 2 and 10% of the total area of industrial, commercial, institutional, and governmental buildings constructed between 1950 and 1973 in Ontario contain sprayed asbestos material. The most likely percentage is between 4 and 5%. The total floor space of buildings constructed between 1950 and 1973 in Ontario is approximately 45 million square metres. A range of 2 to 10% yields an estimate of 0.9 to 4.5 million square metres of floor space in buildings containing sprayed asbestos-containing materials. The most likely estimate within this range is 1.8 to 2.25 million square metres.<sup>33</sup> In Chapter 9 we estimate the net cost of asbestos removal, including the cost of displacing the present occupants of the building, at about \$80 per square metre. Therefore, the total cost of removal of all sprayed material from Ontario buildings would be in the range of \$72 million to \$360 million with the most likely cost lying in the range of \$144 million to \$180 million. These figures do not include the cost of removing asbestos-containing pipe and boiler insulation. While no studies were done in this connection, Pinchin has suggested that the cost of removing all asbestos-containing pipe and boiler insulation would approximate the cost of removing all sprayed asbestos material.

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<sup>31</sup> Ibid., p. 5.9.

<sup>32</sup> Personal communication between Dr. Donald J. Pinchin, D.J. Pinchin Consulting Ltd. and Royal Commission on Asbestos Staff, 10 December 1982.

<sup>33</sup> Pinchin, *Asbestos in Buildings*, pp. 3.18–3.19.

It appears, then, that the total cost of removing all friable asbestos-containing material from Ontario buildings might reach half a billion dollars. Such a figure must be taken as a rough approximation because of the great uncertainty about both the amount of asbestos present in buildings and the range of costs for removal.

This estimated cost, however, should be viewed in conjunction with our conclusion that a universal asbestos removal programme is not warranted. Asbestos in buildings presents no hazard to building occupants, except in a limited number of circumstances, specified in Chapter 9, Section E. Cleaning staff and maintenance workers, if our recommendations are followed, can generally use safe procedures to limit their exposure to asbestos fibres. Removal is appropriate only when workers cannot be adequately protected by other means.

## **C.2 Choosing Among Control Procedures**

Let us consider the circumstances in which it would be appropriate to use management and custodial control, enclosure, encapsulation, or removal to deal with an asbestos problem. To do this, each option must be defined and its effects explored.

### **(a) Management and Custodial Control**

The first control option is management and custodial control. Management and custodial control begins with recording the location of any asbestos detected in the building, as outlined in Recommendation 10.2. Regular building workers, including custodial and maintenance staff, should be informed of the possible risks they face, and they should be educated to control these risks. Worker training should include instruction about the known location of asbestos-containing material in the building and about safe work practices. For example, training in wet-cleaning methods, and in the use of special equipment, such as respirators and high efficiency particulate air (HEPA) filtered vacuums, might be appropriate. Equipment reasonably necessary for adequate worker protection should be made available. Locations in the building containing asbestos should be regularly examined; any loose material should be cleaned up, and any damage to the asbestos-containing material should be repaired.

Management and custodial control can best protect workers and building occupants from elevated fibre exposures if appropriate procedures are carefully followed. If the programme is inadequately managed and carried out, it may have no effect whatsoever. Moreover, because the asbestos remains in place, good management must be exercised for the indefinite future, or until the asbestos is removed.

When should management and custodial control be applied? Management and custodial control should always be instituted once friable asbestos-containing material has been identified in a building. It may be a long-term means of preventing significant exposure to airborne fibres, or it may be merely a temporary precaution taken before a removal project is implemented. The scope of any given programme of management and custodial control should depend on the level of hazard created by the asbestos-containing material. For example, if the asbestos is well enclosed or well encapsulated, it is not necessary to train cleaning staff in special cleaning methods. We accordingly recommend that:

*10.6 The regulation under the Occupational Health and Safety Act on asbestos on construction projects and in buildings should require that once friable asbestos-containing material is found in a building, the building owner must institute a programme of management and custodial control. The scope of the programme should depend on the level of hazard created by the asbestos-containing material and should provide for the institution of safe work practices, including worker training therein, for all regular building custodial and maintenance workers. The programme should continue until the asbestos-containing material is removed from the building.*

To ensure that the scope of any given management and custodial control programme is adequate to protect building workers, we recommend that:

*10.7 The regulation under the Occupational Health and Safety Act on asbestos on construction projects and in buildings should require that a written description of any management and custodial control programme, referred to in Recommendation 10.6 above, be submitted to the Ministry of Labour for approval. The Ministry of Labour should be empowered to approve or vary any programme so submitted, in order to ensure adequate protection for building workers.*

Non-regular maintenance and custodial work, or maintenance and custodial projects, are dealt with in Section D of this chapter.

While it should be the building owner's responsibility to institute a programme of management and custodial control once friable asbestos is discovered in the building, we recognize that building owners may enter into contracts regarding custodial and maintenance services in their buildings. Accordingly, direct responsibility for worker training and safe work practices under a management and custodial control programme might be shifted from an owner to a contractor. We therefore recommend that:

*10.8 The regulation pursuant to the Occupational Health and Safety Act on asbestos on construction projects and in buildings should govern the operations of a contractor who contracts with a building owner to take responsibility for worker training and safe work practices under a management and custodial control programme, so that the contractor would have the same responsibility as the building owner for ensuring that the relevant terms of the management and custodial control programme are met.*

It is important that building owners communicate information regarding locations of friable asbestos-containing materials in a building to contractors, so that provisions can be made for worker training and safe work practices. In order to encourage thorough disclosure of potential asbestos hazards by building owners to contractors, it is necessary that every contract for renovation, maintenance, or custodial work specify all known locations of friable asbestos in the building which might be disturbed. Furthermore, in order both to encourage full disclosure by owners and to ensure that it is not contrary to the financial interests of contractors to take precautions for worker protection, the costs of precautions for worker protection against asbestos hazards discovered in the course of the work should be borne by owners. This might be accomplished by way of regulation under the *Occupational Health and Safety Act*, by way of amendment to that Act, or by way of regulation pursuant to an amendment to the regulation-making power under that Act. We accordingly recommend that:

*10.9 The Ministry of Labour should take steps to require that every contract for renovation, maintenance, or custodial work specify all known locations of friable asbestos-containing materials in the building which might be disturbed. If, in the course of the work, friable asbestos-containing materials of which the contractor was not informed are discovered in locations which could create some risk to workers, adequate precautions for worker protection should be taken, at the sole expense of the building owner.*

Pinchin has suggested that management and custodial control may be a satisfactory long-term approach to friable asbestos-containing pipe and boiler insulation, if no work is to be performed on the material. In our view, this is indeed the most satisfactory approach in most instances because it involves the least disturbance and hence the least exposure. The steps involved would include ensuring that the wrapping surrounding the insulation is intact and painted, to minimize any possibility of fibre release. If the wrapping is damaged, it should be repaired following proper procedures. Management and custodial control may also be a suitable long-term solution for asbestos-containing friable fireproofing insulation which is in good condition, is not damaged, and is not likely to be disturbed.

**(b) Enclosure**

The second control option is enclosure of the asbestos-containing material. Enclosure can be highly effective in protecting building occupants and workers from asbestos fibre release if the enclosure is carefully constructed and remains intact. If the covering on pipe and boiler insulation is damaged, enclosure which repairs the damaged covering may effectively prevent fibre release, unless work is to be performed on the material. Building spaces which are difficult to access but which contain friable asbestos may be protected by enclosure if it is unlikely that access to such spaces for building work will be required.

Construction of the enclosure itself can generate high fibre levels, requiring worker protection during the installation. (See Recommendation 10.17.) Continued management and custodial control is necessary as the asbestos is still in the building; any breach of the enclosure would raise the possibility of fibre release.

**(c) Encapsulation**

The third control option is encapsulation. Encapsulation is useful for pipe insulation, which can be wrapped and painted or re-jacketed, and for sprayed insulation, which is in good condition and which can be thoroughly penetrated by the encapsulant. If the sprayed insulation is in poor condition or cannot be thoroughly penetrated by the encapsulant, it may continue to deteriorate after encapsulation, with pieces of encapsulated insulation falling loose. In such cases, the ultimate effectiveness of the encapsulation is greatly reduced, or even negligible. We accordingly recommend that:

*10.10 The regulation under the Occupational Health and Safety Act on asbestos on construction projects and in buildings should provide that where removal, enclosure, or encapsulation of sprayed asbestos-containing insulation is contemplated, encapsulation should only be an option if that insulation is in good condition and is sufficiently thin that it can be thoroughly penetrated by the encapsulant, or if removal or enclosure are not practicable.*

We note that if sprayed asbestos-containing insulation is sufficiently strong to support an encapsulant and is unlikely to be disturbed by occupants or workers, encapsulation is probably not necessary; the material is unlikely to release significant fibre quantities without encapsulation.

Encapsulation may reduce but not eliminate the problem of friable asbestos in the building. Because the encapsulated material remains in the building, ongoing management and custodial control is required. Then, even when the material is well sealed, building occupants may feel concern,

however unwarranted, about the presence of asbestos. Sealed insulation is far more difficult to remove than unsealed insulation. Because the encapsulant does not usually penetrate the entire depth of asbestos-containing pipe insulation, a hazard of fibre release continues to exist for workers who must remove sections of such insulation.

Encapsulation may be useful after asbestos removal procedures to seal down loose fibres that may have been missed. If ceiling tiles are re-used after asbestos removal, they should be cleaned and sometimes coated with a layer of paint or encapsulant to seal in any residual asbestos-containing dust. Encapsulation is also useful in small areas where removal is impractical or re-insulation is not feasible.

#### **(d) Removal**

The fourth control option is removal. Removal is highly effective in protecting workers from elevated levels of asbestos fibres, assuming that the removal work is carefully completed. Interestingly, however, the immediate effect of asbestos removal on airborne asbestos fibre levels in buildings is to leave them unchanged or to increase them. Table 10.2 shows the results of air monitoring in buildings containing sprayed friable asbestos insulation material before the start of a removal project, outside the work area during the course of removal, and inside the building after completion of a removal project. Fibre levels inside buildings are generally quite low both before and after removal, but in general are higher immediately after removal than before. Presumably this increase in fibre levels arises from the high dust levels generated during removal and the impossibility of cleaning all dust from a building after a project is completed. One would expect that after some time, whether a period of days or weeks, the fibre levels would decrease. The table also shows that a removal project can cause elevated fibre levels outside the work area if proper controls are not applied.

Pinchin monitored the removal of asbestos insulation from a boiler and some piping, during which great care was taken to minimize airborne fibre concentrations.<sup>34</sup> Water was applied to the insulation being removed, where convenient, in an effort to damp down fibres being released. Even with this wetting, fibre levels were well in excess of 5 fibres per cubic centimetre (f/cc) and may have exceeded 10 f/cc. As work practices were further improved, fibre levels were reduced to a range of 3.8 to 6.1 f/cc. Airborne fibre levels in the vicinity of the project immediately after removal were no lower than before and, in fact, were generally higher. We interpret these data as we do those for sprayed asbestos removal; we assume that within days or weeks after removal, fibre levels would be as low as before. The benefit from removal, then, is not a reduction in average fibre levels, which

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<sup>34</sup>Ibid., pp. 7.21–7.24.

Table 10.2  
Air Monitoring Results from Sprayed Asbestos Insulation Projects\*

Project Number	Before Start of Project					During Work Outside Area		After Contract Completion			
	Optical Microscopy		Transmission Electron Microscopy			Optical Microscopy		Optical Microscopy		Transmission Electron Microscopy	
	Fibres	f/cc	Total Asbestos	Fibres	ng/m <sup>3</sup>	Fibres	f/cc	Fibres	f/cc	Total Asbestos	Fibres >5.0 µm
			f/cc		ng/m <sup>3</sup>					ng/m <sup>3</sup>	ng/m <sup>3</sup>
1											
		0.024	0.040	2.345	<0.005		0.06	0.056	0.20	<0.004	—
		0.020	0.010	0.092	<0.005		0.04	0.062	2.05	<0.004	—
Average:			0.011	0.044	<0.005		0.01	0.052	2.00	<0.004	—
			0.047	0.330	<0.005		0.17		0.40	<0.004	—
		0.022	0.027	0.703	<0.005	(a)	0.07	0.057	1.16	<0.004	—
2		<0.1	0.024	4.53	0.003		0.1	0.027	154.2	0.002	120.0
		<0.1	0.017	2.05	0.002		0.1	0.059	64.2	0.008	53.1
		<0.1	0.019	3.14	0.004		0.1	0.075	177.3	0.013	148.0
Average:			0.005	1.01	0.002						
		<0.1	0.016	2.68	0.003	0.2(b)	0.1	0.054	131.9	0.008	107.0
		<0.1	0.016	2.520	<0.002		0.1	0.028	16.5	0.002	14.0
3		<0.1	0.011	1.405	0.002		<0.1	0.036	97.3	0.007	92.0
		<0.1	0.017	1.305	0.002		<0.1	0.014	60.3	0.007	60.0
		<0.1	0.015	1.743	0.001	0.63(c)	<0.1	0.026	58.0	0.005	55.3
Average:		<0.1	0.010	1.109	0.004		<0.1	0.008	2.68	0.002	2.5
		<0.1	0.009	4.309	0.002		<0.1	0.011	0.40	<0.003	—
		<0.1	0.050	4.600	0.003			0.010	0.25	<0.003	—
4		<0.1	0.023	3.339	0.003	2.21(d)	<0.1	0.010	1.11	0.001	0.8
		<0.1	0.077	(e)	0.004		0.100	0.14	(e)	0.004	(e)
		0.004	0.020	(e)	<0.001		0.007	0.72	(e)	0.080	(e)
Average:		0.004	0.013	(e)	0.002		0.011	0.74	(e)	<0.001	—
		0.003	0.037		0.002	0.02(f)	0.039	0.53		0.028	
		0.004	0.015	(e)	0.001		0.028	0.100	(e)	<0.001	—
6		0.003	0.014	(e)	<0.001		0.019	0.048	(e)	<0.001	—
		0.004	0.007	(e)	0.001		0.019	0.210	(e)	0.005	(e)
		0.004	0.012		0.001	0.009(g)	0.022	0.119		0.002	

Table 10.2 (continued)  
Air Monitoring Results from Sprayed Asbestos Insulation Projects\*

Project Number	Before Start of Project				During Work Outside Area				After Contract Completion			
	Optical Microscopy Fibres	Transmission Electron Microscopy			Optical Microscopy Fibres	Asbestos Fibres >5.0 µm	Transmission Electron Microscopy			Total Asbestos Fibres	Asbestos Fibres >5.0 µm	
		Total Asbestos Fibres	f/cc	ng/m <sup>3</sup>			Total Asbestos Fibres	f/cc	ng/m <sup>3</sup>			
		f/cc	ng/m <sup>3</sup>	f/cc		ng/m <sup>3</sup>	f/cc	ng/m <sup>3</sup>	f/cc	ng/m <sup>3</sup>	f/cc	ng/m <sup>3</sup>
7	<0.001	0.013	(e)	<0.001	(e)	0.002	0.040	(e)	<0.001	—		
	0.003	0.012	(e)	<0.001	(e)	0.003	0.498	(e)	0.034	(e)		
	0.002	0.024	(e)	<0.001	(e)	0.004	0.008	(e)	0.003	(e)		
Average:	0.002	0.016		<0.001		0.003(h)	0.182		0.012			
8a	0.04	(e)	(e)	0.004	(e)	0.00	(e)	(e)	0.01	(e)		
	0.02					0.3						
Average:	0.03			0.004		0.19			0.01			
8b	<0.01	0.019	0.13	<0.004	—	0.04	0.172	1,301.1	0.024	1,200.0		
						0.09	0.340	22.9	<0.006	—		
Average:	<0.01	0.019	0.13	<0.004	—	0.07	0.256	662.0	0.012	600.0		

Notes: \* All results from area samples. Measured by NIOSH Method P & CAM 239.

(a) No samples taken.

(b) Average of 6 measurements ranging from <0.1 to 0.4 f/cc.

(c) Average of 9 measurements ranging from <0.1 to 2.8 f/cc.

(d) Average of 7 measurements ranging from 0.1 to 8.7 f/cc.

(e) Figure not reported.

(f) Average of 7 measurements ranging from 0.006 to 0.039 f/cc.

(g) Average of 8 measurements ranging from 0.006 to 0.013 f/cc.

(h) Average of 12 measurements ranging from 0.002 to 0.16 f/cc.

(i) Average of 5 measurements ranging from 0.01 to 0.09 f/cc.

SOURCE: Adapted from: Donald J. Pinchin, *Asbestos in Buildings*, Royal Commission on Asbestos Study Series, no. 8 (Toronto: Royal Commission on Asbestos, 1982), Table III, p. 7.12.

tend to be low to begin with. Rather, removal prevents elevated fibre exposures for those who must work on or near the asbestos-containing material.

If the asbestos-containing material is in good condition, is not damaged, and is not disturbed by occupants or workers, removal is not warranted. Removal undertaken in these circumstances could increase rather than decrease the total fibre exposure of workers and occupants. In this context it should be noted that wet-applied, or cementitious, sprayed asbestos insulation is more likely to be in good condition than is dry-applied sprayed asbestos insulation. We report in Chapter 9, Section D that Nicholson did not find elevated airborne fibre levels in buildings with wet-applied sprayed asbestos insulation.

### C.3 Demolition

We have not found data indicating the fibre levels experienced by demolition workers when dismantling a building or structure that contains friable asbestos. Neither have we seen evidence on asbestos fibre levels in the surrounding ambient air during demolition. We know, however, that fibre levels in the breathing zone of workers removing sprayed asbestos-containing insulation or removing asbestos-containing pipe and boiler insulation were far above the recently adopted Ontario control limits, even with careful work procedures, so that respirators were required for worker protection.<sup>35</sup> In addition, fibre levels outside the work area of an asbestos removal project could be substantially elevated if careful procedures are not followed to seal off the work area. In the absence of other information, we believe it is prudent to assume that demolition may cause as much fibre release as does asbestos removal. Since most buildings with sprayed asbestos insulation and pipe and boiler lagging are now between 10 and 30 years old, the problem of exposure from demolition will be much greater in the future than it is at present.

Two control options are conceivable. One is to remove friable asbestos-containing material before demolition, using safe work practices. The other is to develop procedures that would ensure the health and safety of workers on the demolition site, and of the general public outside, while demolishing a building containing friable asbestos.

We have found no studies that describe procedures adequate for worker protection and the protection of the public when demolishing a building which still contains friable asbestos material. Even if one could saturate the asbestos material with water and enclose the area of the building being demolished, the waste carried out of the building would be a

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<sup>35</sup> Ibid., p. 7.25.

mixture of normal demolition wastes and friable asbestos products. This would all have to be carefully enclosed until safely deposited at a dump site, an extremely difficult task given the huge volume of waste that would be involved. This seems impractical, and we must assume it to be so until studies show otherwise. We, therefore, reject the option of leaving friable asbestos in a building and attempting to control fibre release during and after demolition.

U.S. EPA regulations require that friable asbestos-containing material be removed from a building prior to demolition, where more than 80 linear metres of friable asbestos material are to be disturbed.<sup>36</sup> Friable asbestos material is to be wetted prior to removal,<sup>37</sup> and is to be disposed of safely.<sup>38</sup> The EPA is to be notified at least 10 days before demolition of a building containing friable asbestos.<sup>39</sup>

We believe that removal of asbestos just prior to demolition may be considerably less expensive than asbestos removal which is to be followed by reoccupancy. If the building is to be demolished, much less care need be taken to avoid water damage or other damage to furniture and fixtures than if it is to continue to be occupied. Ceiling tiles, lights, and other fixtures that must be removed for asbestos removal need not be replaced afterwards. As well, costs associated with displacing occupants are avoided. We therefore recommend that:

*10.11 The regulation under the Occupational Health and Safety Act on asbestos on construction projects and in buildings should require that the owner of a building or structure ensure that prior to the demolition or partial demolition of a building or structure, all friable asbestos-containing materials which might be disturbed are removed from the building or structure, following procedures for removal referred to in Recommendations 10.14 and 10.17.*

We note that the removal of asbestos prior to demolition is consistent with the Ministry of Labour's Proposed Regulation Respecting Asbestos on Construction Projects (PRRACP).<sup>40</sup>

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<sup>36</sup>U.S., Environmental Protection Agency, *National Emission Standard for Asbestos*, 40 CFR 61.22(d)(4)(i).

<sup>37</sup>40 CFR 61.22(d)(4)(ii).

<sup>38</sup>40 CFR 61.22(j).

<sup>39</sup>40 CFR 61.22(d)(2).

<sup>40</sup>Ontario, Ministry of Labour, Occupational Health and Safety Division, "Proposed Regulation Respecting Asbestos on Construction Projects and Related Codes," presented at a Public Meeting, 17 January 1983, Toronto. (Mimeographed.) This "Proposed Regulation. . ." is a revision of the "Notice of Proposed Regulation: Designated Substance — Asbestos on Construction Projects," *The Ontario Gazette*, vol. 115-33, Saturday, 14 August 1982, pp. 3194-3197.

Having determined that building demolition must be preceded by removal of friable asbestos, we turn to the problem of determining when asbestos is present. The only reliable way to determine whether friable asbestos-containing material is present in a building about to be demolished is to conduct an inspection of the building prior to demolition, and we have so recommended. (See Recommendation 10.1.) The results of such inspections should be communicated to demolition contractors, so that demolition contracts can provide for the costs of removing asbestos safely, thereby ensuring worker safety. This could be accomplished by way of regulation under the *Occupational Health and Safety Act*, by way of amendment to that Act, or by way of regulation pursuant to an amendment to the regulation-making power under that Act. We accordingly recommend that:

**10.12** *The Ministry of Labour should take steps to require that every contract for demolition specify all known locations of friable asbestos-containing materials in the building or structure which might be disturbed by the demolition work.*

It is always possible that, notwithstanding careful inspection, some friable asbestos-containing material will be discovered during the process of demolition. If the demolition contractor is on a fixed-price contract, it would be financially advantageous to proceed as if the material were not hazardous. The building owner, too, does not have an incentive to deal safely with such material. In order to ensure that it is not contrary to the financial interests of demolition contractors to take such steps as are necessary for the removal of asbestos hazards not specified in the demolition contract, the costs of such removal should be borne by the owners. This could be accomplished by way of regulation under the *Occupational Health and Safety Act*, by way of amendment to that Act, or by way of regulation pursuant to an amendment to the regulation-making power under that Act. We accordingly recommend that:

**10.13** *The Ministry of Labour should take steps to provide that all contracts for the demolition of a building or structure in Ontario shall be deemed to include a clause which provides for supplemental payment to the demolition contractor, on a time and materials basis, for all reasonable expenses incurred in removing any friable asbestos-containing material which was not specified in the demolition contract.*

We anticipate that the construction industry would develop a standard clause embodying the above recommendations, for insertion in all demolition contracts.

## D. Safe Procedures for Work with Asbestos

### D.1 Recommended Work Practices

Workers and persons in the vicinity of work may be exposed to asbestos as a result of enclosure, encapsulation, or removal of asbestos or as a result of non-control work, such as demolition, renovation, maintenance, or custodial work which disturbs asbestos. The degree of precaution required for any job depends on the dustiness of the job.

There are two ways to approach the protection of building and construction workers. The first approach specifies control limits and requires regular air monitoring to ensure that the control limits are observed. This is the approach, described in Chapter 7, that currently applies in Ontario to all workplace exposures, except those occurring on construction projects. The second approach involves specifying with some precision the procedures which should be followed when performing particular types of work. This is the approach generally used for the occupational health and safety protection of workers on construction projects in Ontario, specified by the Ministry of Labour's Proposed Regulation Respecting Asbestos on Construction Projects and endorsed by us in the introduction to this chapter.

The PRRACP defines a "hazardous work area" as "... that part of a project where material containing asbestos is used, handled, dealt with, disturbed or removed and as a result thereof airborne asbestos is likely to be inhaled or ingested by a worker."<sup>41</sup> Two levels of precaution may be required by the PRRACP in a "hazardous work area." In *all* hazardous work areas, the following are required:

- (i) The Ministry of Labour must be notified before work begins (section 4).
- (ii) Warning signs and barriers must be erected around the work area (section 5).
- (iii) Workers must wear respirators and protective clothing (section 6).
- (iv) Washing facilities must be made available (section 7).
- (v) Eating, drinking, smoking, and chewing materials are prohibited in the work area [section 7(4)].
- (vi) The work area must be cleaned regularly and carefully (section 8).

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<sup>41</sup> Ibid., s. 3(1).

- (vii) Power tools must have local exhaust [section 9(1)].
- (viii) Spraying asbestos is prohibited [section 9(2)].
- (ix) Waste material must be carefully packed and disposed of (section 10).
- (x) Workers must be properly trained (section 11).
- (xi) An asbestos work record must be maintained for each worker (section 14).
- (xii) Workers must be subject to medical surveillance (sections 15–18 inclusive).

Where a hazardous work area exists and asbestos is to be stripped, removed, or encapsulated, further precautions are required by Section 13:

- (i) The work area must be enclosed and sealed.
- (ii) The enclosure must be inspected and repaired daily.
- (iii) Asbestos materials to be removed must be wetted, where practicable.
- (iv) Exits must have showers and change rooms.
- (v) The work area must be carefully cleaned before work commences.
- (vi) Before removing the enclosure, the work area must be washed and vacuumed, and all asbestos must be removed or encapsulated.

The definition of “hazardous work area,” quoted above, is broad, covering a wide range of activities, including asbestos removal, enclosure, or encapsulation; and renovation or maintenance of buildings or of plumbing, heating, ventilating, air conditioning, electrical or other systems. Any of these activities could be major, disturbing hundreds of square metres of insulation, or small, disturbing only a few handfuls of asbestos. Removing ceiling tiles covering an asbestos-sprayed ceiling, or installing a valve in asbestos-insulated pipe as part of a construction project, might create a “hazardous work area.” Furthermore, we have recommended that the PRRACP should be extended to minor maintenance and custodial activities. The variety of “hazardous work areas” will be further enhanced given our recommendation that the Ministry of Labour should frame a regulation that encompasses building maintenance and custodial work as well as construction projects.

Because of the variety of work situations to be covered, we believe that the two levels of precautions envisaged in the PRRACP are insuffi-

cient. The general hazardous work area precautions would be excessive for maintenance activities involving little asbestos disturbance and perhaps for encapsulation of pipe and boiler insulation in good condition. It is not plausible that the Ministry of Labour would be notified, barriers erected, workers trained, and worker records maintained every time a hole is drilled in asbestos-cement water pipe, every time an electrician removes a ceiling tile below some sprayed asbestos, or every time a valve on an asbestos-insulated pipe is repaired. Regulatory enforcement, whether on construction projects or in buildings, would be jeopardized if unreasonable burdens are imposed in connection with work which involves minimal asbestos exposure. Accordingly, we propose that three levels of precautions be defined; that the two levels of precautions contained in the PRRACP, with small modifications, become the intermediate and maximum precautions; and that a new set of minimum precautions be devised.

The minimum precautions would require that the worker wear an approved respirator as prescribed in section 1 of the Code for Respiratory Equipment of the PRRACP and that the work area be cleaned using wet methods or a high efficiency particulate air filtered vacuum when work is completed. Eating, drinking, smoking, and chewing materials should be prohibited in the work area, as these interfere with the proper use of respirators. Power tools used on asbestos-containing materials should be equipped with high efficiency particulate air filtered vacuums. Workers should be properly instructed. The Ministry of Labour need not be notified, and exposure records need not be kept. These precautions will be referred to as "Precautions A."

The intermediate precautions should be similar to those described in the PRRACP, in sections 4, 5, 6, 7, 8, 10, and 11 outlined above, with minor modifications. Section 5(b) requires that a hazardous work area be separated from the rest of the project by "... the placing of barriers to mark its boundaries." These barriers could be ropes or sawhorses. In accordance with our conclusion that these precautions should not apply to the least hazardous work, we believe that some effort should be made to contain airborne dust within the work area. Accordingly, the hazardous work area should be separated from the rest of the project by a barrier capable of limiting the spread of asbestos fibres outside the work area. An example of such a barrier would be a plastic sheet surrounding the work area, taped to the ceiling, but not sealed at the floor or at entrances.

It is well established that wetting asbestos greatly reduces airborne fibre levels, yet this is not required by sections 4 to 11 inclusive of the PRRACP. In some cases, wetting may be easy and beneficial in reducing dust levels. In other cases, wetting may be impractical because of electrical hazards, damage to furniture or fixtures, or other conditions. We believe that in situations calling for the application of more than minimal precau-

tions, whenever practicable, friable asbestos-containing materials should be wetted before they are disturbed. We will refer to these intermediate precautions as “Precautions B.”

The maximum precautions, or “Precautions C,” should be as described in section 13 of the PRRACP, outlined above. We are satisfied that these procedures are sufficient both to provide worker protection and to leave the building in a safe condition for further occupancy. They are, however, quite general. Many asbestos control contracts involve specifications which establish precisely how the work is to be performed. An example of such specifications can be found in the Foundation of the Wall and Ceiling Industry’s *Guide Specifications for the Abatement of Asbestos Release from Spray- or Trowel-Applied Material in Buildings and Other Structures*. These highly detailed specifications are set out in Appendix H to the Pinchin study.<sup>42</sup> They provide detailed provisions both for protecting workers on the job and for ensuring that the building is in a safe condition when the work is completed. These specifications are consistent with the maximum precautions we have defined. While they are far too detailed for enactment as regulations, they could be used by the building owner to assist in securing competent performance from a contractor. In light of the above, we recommend that:

**10.14** *The regulation under the Occupational Health and Safety Act on asbestos on construction projects and in buildings should distinguish among three levels of precautions:*

“Precautions A”:

*The minimum precautions, or “Precautions A,” should include the following:*

- (i) *Workers must wear respirators in the hazardous work area [section 6, Proposed Regulation Respecting Asbestos on Construction Projects (PRRACP)].*
- (ii) *Power tools used in the hazardous work area on asbestos-containing material may be operated only in conjunction with high efficiency particulate air filtered vacuums (section 9, PRRACP).*
- (iii) *Workers must be educated as to the risks they face when working with asbestos and trained in the appropriate procedures for minimizing those risks (similar to section 11, PRRACP).*

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<sup>42</sup>Pinchin, *Asbestos in Buildings*, Appendix H.

“Precautions B”:

*The intermediate precautions, or “Precautions B,” should include, in addition to the precautions set out above as “Precautions A,” the following:*

- (i) The Ministry of Labour must be notified before the hazardous work begins (section 4, PRRACP).*
- (ii) The work area must be separated from the rest of the project by a barrier capable of limiting the spread of asbestos fibres outside the work area (to be added to PRRACP).*
- (iii) Protective clothing must be worn by all workers (section 7, PRRACP).*
- (iv) Washing facilities must be available to workers (section 7, PRRACP).*
- (v) The hazardous work area must be properly and regularly cleaned (section 8, PRRACP).*
- (vi) No loose asbestos is to remain on the floors (section 10, PRRACP).*
- (vii) Asbestos-containing materials must be wetted prior to disturbing them, where practicable (section 13, PRRACP).*
- (viii) Asbestos work records must be kept for all workers involved in the hazardous work (section 14, PRRACP).*
- (ix) All workers involved in the hazardous work are to be subject to medical surveillance (sections 15–18, PRRACP).*

“Precautions C”:

*The maximum precautions, or “Precautions C,” should include, in addition to the precautions set out above as “Precautions ‘A’ and ‘B,’ ” the following:*

- (i) The work area must be enclosed and sealed (section 13, PRRACP).*
- (ii) Showers and change rooms must be available to all workers (section 13, PRRACP).*
- (iii) The work area must be cleaned prior to the commencement of the work and subjected to a thorough two-stage cleanup after the work is completed (section 13, PRRACP).*

In applying two levels of precautions, the PRRACP distinguishes only between asbestos removal and encapsulation work, on the one hand, and all other construction work where asbestos dust is likely to be inhaled or ingested by a worker, on the other hand. An alternative approach would draw distinctions among types of control work causing high, moderate, and low asbestos exposure risks. For example, encapsulation of pipe and boiler insulation frequently requires only wrapping the existing insulation with fabric and painting the fabric. This may be considerably less dusty than encapsulating sprayed insulation, which requires directing a blast of sprayed

paint at the surface. It is far less dusty than asbestos removal. Then, removing a cementitious wet-applied sprayed insulation may be less dusty than removing a dry-applied sprayed insulation. We conclude that different asbestos control projects, including removal, encapsulation, and enclosure, may generate different dust levels and should therefore require different precautions, depending on the type of work.

In addition to the type of work, the size of a particular job may be relevant to the decision as to appropriate work practices. Removal, encapsulation, or enclosure which disturbs only small amounts of asbestos might not require precautions even as strict as the basic PRRACP precautions (our "Precautions B"). We, therefore, propose that control work be classified as small, medium, and large, depending on the area of asbestos to be worked on.

The U.S. EPA recognizes the importance of the size of a job by exempting buildings with less than 15 square metres of sprayed or boiler insulation, or less than 80 linear metres of pipe insulation, from following its work practices regulation.<sup>43</sup> In view of our recommendation that a minimum set of precautions, "Precautions A," be developed, we believe that total exemption is unwarranted. (See Recommendation 10.14.) As well, we propose that the size definition should be in square metres for pipe insulation as well as for sprayed and boiler insulation, since stripping a large diameter pipe will generally generate more dust than stripping a small diameter pipe of the same length. Furthermore, the 15 square metre area of insulation exempted by the U.S. EPA regulations is substantial, and too large in our view to merit classification as "small." We suggest that a small job might be defined as involving 5 square metres or less of insulation surface, and a large job as involving 20 square metres or more. These numbers are, however, a matter of judgement on which the Ministry of Labour should seek advice from industry and labour. We therefore recommend that:

*10.15 The Ministry of Labour should consult with industry and labour to develop numerical definitions of areas of insulation to be classified as "small," "medium," and "large" for the purpose of determining which level of precautions, whether "Precautions 'A,' 'B,' or 'C' " referred to in Recommendation 10.14 above, is to be applied to asbestos control work projects of varying types and sizes.*

Turning to non-control work, including maintenance, renovation, and custodial work, there may be great variations in asbestos dust levels caused and in the precautions required for worker protection. Several factors

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<sup>43</sup>U.S., Environmental Protection Agency, *National Emission Standard for Asbestos*, 40 CFR 61.22(d).

might be considered in the determination of the appropriate precautions for a particular project. The extent of contact with the asbestos would be important; direct contact with the asbestos in the location where it was originally applied is generally more hazardous than contact only with asbestos which has fallen from its place of installation, because the quantities involved in the latter case tend to be far smaller than in the former. The larger the area of asbestos to be disturbed, the greater would be the required precautions. If the asbestos is crocidolite or amosite, greater precautions are indicated than if the asbestos is chrysotile, because work with dry crocidolite or amosite is likely to be dustier than work with dry chrysotile and because chrysotile may be easier to wet than the amphiboles.<sup>44</sup> Finally, the higher the asbestos content of the material, the greater would be the required precautions. We therefore recommend that:

*10.16 The Ministry of Labour should consult with industry and labour to develop definitions of major, intermediate, and minor renovation, maintenance, and custodial projects for the purpose of determining which level of precautions, whether "Precautions 'A,' 'B,' or 'C' " referred to in Recommendation 10.14 above, is to be applied in each instance.*

Table 10.3 shows how such a regulation might appear. It specifies three levels of precautions, "A," "B," and "C," as defined in Recommendation 10.14. It allows the application of these precautions to differ depending on the type of work and the size of the job or the extent of the hazard. The entries in the table are intended as examples only and not as specific recommendations. Deciding which precautions are appropriate for each type of work and scope of project should require consultation by the Ministry of Labour with representatives of industry and labour. We therefore recommend that:

*10.17 The Ministry of Labour should consult with industry and labour to determine, for the purposes of the regulation under the Occupational Health and Safety Act on asbestos on construction projects and in buildings, the appropriate precautions to be applied to large, medium, and small control jobs and to major, intermediate, and minor renovations and maintenance and custodial projects, distinguishing, where appropriate, among wet-sprayed insulation, dry-sprayed insulation, and pipe and boiler insulation.*

The three levels of precautions described in Recommendation 10.14 above are designed with a view to *specified* types of work generally per-

<sup>44</sup>Pinchin, *Asbestos in Buildings*, p. 7.25; and Ontario, Royal Commission on Asbestos, Transcript of Public Hearings [hereafter RCA Transcript], Evidence of Mr. Ross Hunt, 16 June 1982, Volume no. 41, p. 77.

Table 10.3  
Procedures for Safe Work with Asbestos in Buildings

Procedures (to be applied as indicated below)  
A — Minimum precautions  
B — Intermediate precautions  
C — Maximum precautions

Control Work	Size of Job		
	Large	Medium	Small
Removal			
Pipe and Boiler	C	C	B
Spray — Dry	C	C	B
Wet	C	B	B
Encapsulation, Enclosure			
Pipe and Boiler	B	B	A
Spray — Dry*	C	C	B
Wet*	C	B	A
Renovation, Maintenance, and Custodial Work			
	Extent of Work, Dust Level, Fibre Type		
	Major	Intermediate	Minor
Renovation			
Pipe and Boiler	Control**	B	A
Spray — Dry	Control	Control	B
Wet	Control	B	A
Maintenance and Custodial Projects	B	B	A
Regular Maintenance	M + CC***	M + CC	M + CC
Regular Custodial Work	M + CC	M + CC	M + CC
Other	A		

Notes:   \*Encapsulation is often not an appropriate control method for sprayed insulation. See Recommendation 10.10.  
      \*\*\*"Control" means removal, encapsulation, or enclosure.  
      \*\*\*\*"M + CC" refers to management and custodial control. See Recommendations 10.6 to 10.9.

formed in buildings and on construction projects. Work situations may occur which cause asbestos dust release and potential hazards to workers and which are not specifically covered by Recommendation 10.17. These work situations should not in general cause very elevated dust levels. Examples of these situations might include work on asbestos-containing drywall joining and taping compounds. To ensure that all potentially hazardous work involving asbestos is subject to regulation, we recommend that:

*10.18 The regulation under the Occupational Health and Safety Act on asbestos on construction projects and in buildings should require that types of work in a hazardous work area which are not otherwise dealt with in that regulation shall only be performed in accordance with "Precautions A," described in Recommendation 10.14.*

This is indicated in Table 10.3.

"Precautions A" do not include the keeping of asbestos work records or medical surveillance, because "Precautions A" are designed for relatively low asbestos exposure situations. However, if a worker is often exposed to low asbestos exposure situations, the cumulative exposure may be such as to warrant the keeping of asbestos work records and medical surveillance. We accordingly recommend that:

*10.19 The regulation under the Occupational Health and Safety Act on asbestos on construction projects and in buildings should provide that where a worker frequently performs work calling for "Precautions A," described in Recommendation 10.14, asbestos work records should be kept for that worker and that worker should be subject to medical surveillance, as if the work called for "Precautions B."*

Comments to the Ministry of Labour on the PRRACP questioned the feasibility of enclosing asbestos removal work areas when the material is outdoors, as is the case with exterior piping.<sup>45</sup> The Ministry replied that "... if it can be shown that the dispersion of asbestos is being controlled without the use of an enclosure, alternative procedures are allowed under the equivalency section."<sup>46</sup> The equivalency section of the PRRACP is section 19, which states:

<sup>45</sup>Written submissions to the Ontario Ministry of Labour on the "Proposed Regulation Respecting Asbestos on Construction Projects," by: Canadian Chemical Producers' Association, #969, 26 November 1982; Dow Chemical Canada Inc., #962, 28 October 1982; Asbestos Information Association/North America, #968, 28 October 1982; Du Pont Canada Inc., #954, 29 October 1982; and Ontario Petroleum Association, #971, 6 December 1982.

<sup>46</sup>Ontario, Ministry of Labour, "Asbestos Construction Regulation," text of presentation made in Toronto, Queen's Park, 17 January 1983, p. 29. (Mimeographed.)

For the purpose of this Regulation, the methods, procedures, composition, design, size or arrangement that may be used may vary from that prescribed in this Regulation or required in the codes issued by the Ministry if the protection or the factors of accuracy and precision afforded thereby are equal to or exceed the protection or the factors of accuracy and precision prescribed in this Regulation or in the codes issued by the Ministry.

An enclosure generally raises the exposure of asbestos workers, lowers the exposure of workers and the general public outside, and prevents the spread of asbestos fibres to the neighbourhood. We understand that currently outdoor asbestos removal is sometimes performed without an enclosure, using large vacuum machines to convey discarded asbestos material and to collect dust, as a local exhaust device. We do not have sufficient information to evaluate this technology. We do, however, believe that working with asbestos outside of buildings will occur with sufficient frequency, particularly in the chemical and petrochemical industries, that the Ministry of Labour should provide more guidance as to what may be acceptable practice. We therefore recommend that:

*10.20 The Ministry of Labour should, in consultation with industry and labour, prepare an alternative set of precautions for asbestos removal work outdoors that would allow the substitution of local exhaust ventilation for the use of an enclosure in situations where enclosure is impracticable. This alternative set of precautions should be included in the regulation under the Occupational Health and Safety Act on asbestos on construction projects and in buildings.*

We recognize that our recommendations regarding safe work practices on construction projects and on custodial and maintenance projects would at times result in some unnecessary precautions being taken. This is, to some extent, inevitable in any scheme of regulation by procedure designed to apply to very diverse types of work. Nonetheless, flexibility should be maximized, within the bounds of safety. We believe that this could be achieved by providing for Ministry of Labour approval of work procedures which, while varying from those prescribed, are capable of providing adequate worker protection.

The equivalency section of the PRRACP (section 19) permits equivalent protection, involving substitute procedures which are just as protective as those prescribed. While we endorse this provision, we believe that it should also be possible to use substitute procedures that are demonstrated to be *adequately* protective. In discussing control limits for fixed workplaces in Chapter 7, we point out that proper enforcement of such limits means that the average worker will be exposed to one-half or less of the exposure value that a control limit specifies. Outside fixed workplaces, we believe that procedures which produce the same outcome will be adequately

protective. Accordingly, when the Ministry of Labour is convinced that substitute procedures, when employed by a trained worker using a reasonable degree of care, will produce the same outcome, it should allow the substitute procedures to be used. We accordingly recommend that:

*10.21 The regulation under the Occupational Health and Safety Act on asbestos on construction projects and in buildings should provide that work procedures may be used which vary from those prescribed if the protection afforded by the variant procedures is equal to or exceeds the protection afforded by the prescribed procedures, or if it is demonstrated to the Ministry of Labour that those variant work procedures would always result in average worker exposures which, in the case of chrysotile, are at or lower than one-half the control limit and, in the case of crocidolite or amosite, are at or lower than one-half the exposure values prescribed in Recommendations 7.13 and 7.15. However, the use of variant work procedures should not in any way detract from requirements that would otherwise apply to the particular work situations regarding worker training, Ministry of Labour notification, asbestos waste handling, cleaning of the hazardous work area, wetting of asbestos, asbestos work records, or medical surveillance.*

The objective of our recommendations in this section is to maintain worker exposure at levels equal to or less than those allowed by the regulations regarding fixed workplaces, to prevent contamination of the rest of the building, and to leave the building clean after work has been performed. We anticipate that air monitoring would be used from time to time in order to demonstrate the necessity of these precautions for achieving the desired fibre levels. The membrane filter method, using phase contrast microscopy analysis, may be appropriate for assessing dusty work where asbestos fibres are expected to be the primary dust component. For work where much non-asbestos dust is expected, or where fibre levels are expected to be below the limits of reliable phase contrast microscopy analysis, electron microscope methods may be necessary. On some work, both measurement methods should be used simultaneously to add to the understanding of the relationship between them. We accordingly recommend that:

*10.22 The Ministry of Labour should conduct air monitoring of control work, renovation work, and of maintenance and custodial work, from time to time, to determine whether the safety precautions referred to in Recommendations 10.14, 10.17, and 10.20 above are sufficient to ensure worker safety or are unnecessarily strict.*

The number of workers across Ontario engaged in work which would be covered by a regulation on asbestos on construction projects and on maintenance and custodial projects is enormous, which creates difficulty in

setting up a programme directed at identifying the exposed workers and communicating with them directly. Nevertheless, an educated labour force is crucial to the successful implementation of any programme of safe work practices. We recommend that:

*10.23 The Ministry of Labour should explore methods of communicating with control, renovation, maintenance, and custodial workers to inform them of the risks they face when working in buildings containing friable asbestos and of the appropriate procedures for minimizing those risks.*

## **D.2 Current Uses of Asbestos-Containing Products in New Construction**

The major types of asbestos-containing construction materials in use today from which fibres might be released are asbestos-cement pipe, asbestos-cement sheet, and asbestos insulation board. In his study for this Commission, Professor Gordon M. Bragg reported that asbestos-cement sheet and pipe are infrequently used in Ontario.<sup>47</sup> The major asbestos-cement pipe operation in Ontario closed in 1980, and only a few small plants continue to manufacture asbestos-cement products in the province. It appears, as well, that the use of asbestos insulation board is limited and declining.

Asbestos-cement pipe generally contains both chrysotile and crocidolite asbestos. Crocidolite represented about 20% of the asbestos content of the asbestos-cement pipe manufactured in Ontario by Johns-Manville until its Scarborough pipe operations ceased in 1980.<sup>48</sup> The asbestos content of asbestos-cement sheet is mostly chrysotile, with amosite and/or crocidolite constituting 20% or less of the asbestos content.<sup>49</sup> Asbestos insulation board includes a wide range of products, with both the type and quantity of asbestos varying from product to product. Some asbestos insulation board products consist of almost pure asbestos while others contain only a small percentage of asbestos.<sup>50</sup>

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<sup>47</sup>Gordon M. Bragg, *The Technical Feasibility and Cost of Controlling Workplace Exposure to Asbestos Fibres*, Royal Commission on Asbestos Study Series, no. 7 (Toronto: Royal Commission on Asbestos, 1982), p. 85.

<sup>48</sup>Information submitted to the Royal Commission on Asbestos by Johns-Manville Canada Inc., 1982. See also, William H. Hallenbeck et al., "Is Chrysotile Asbestos Released from Asbestos-Cement Pipe Into Drinking Water?" *Journal American Water Works Association* 70:2 (January 1978): 97.

<sup>49</sup>Personal communication between Dr. Donald J. Pinchin, D.J. Pinchin Technical Consulting Ltd. and Royal Commission on Asbestos Staff, 14 February 1983.

<sup>50</sup>*Ibid.*

Cutting, drilling, or sawing asbestos-cement materials can release dust which contains asbestos fibres. Table 10.4 shows asbestos fibre exposure levels recorded during work on asbestos-cement sheet and pipe products. Traditional sawing and drilling procedures cause fibre levels well in excess of the new 1 f/cc Ontario workplace control limit and sometimes as much as 20 times this rate. Moreover, to the extent that asbestos-cement products contain crocidolite, the lower crocidolite exposure value envisaged by Recommendation 7.13 would be the proper standard for comparison. Other estimates of fibre levels generated by work on asbestos-cement products may be found in Saheed et al.<sup>51</sup>

Procedures for controlling fibre release during work on asbestos-cement products involve either the use of tools that do not generate significant dust levels or the use of vacuum suction attachments which, when connected to the tools, draw away most dust.<sup>52</sup> However, we have not seen evidence to convince us that the fibre levels which remain are so low as to render the use of respirators unnecessary. The data contained in Table 10.4 suggest that work with asbestos insulation board is dustier than work with asbestos-cement products.

We conclude that "Precautions A," described in Recommendation 10.14 in the previous section, should apply to work with asbestos-cement products and with asbestos insulation board. This is provided for in Recommendation 10.18 dealing with types of work in a hazardous work area not otherwise specifically covered by our recommendations for work procedures on construction projects and on maintenance and custodial projects. We acknowledge that it may be possible to demonstrate that procedures for working with these products which vary from "Precautions A" would, when employed by a trained worker using reasonable care, always result in worker exposures which, in the case of chrysotile, are lower than one-half the control limit and, in the case of crocidolite or amosite, are lower than one-half the exposure values prescribed in Recommendations 7.13 and 7.15. Should this be the case, Recommendation 10.21 would apply.

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<sup>51</sup>W. Saheed et al., "Distribution and Concentration of Asbestos Dust in Commonplace Construction Activities," a project conducted jointly by the University of Toronto, Department of Preventive Medicine and Biostatistics and the Construction Safety Association of Ontario, Research and Development Department, Toronto, 1978, Tables A and B. (Mimeographed.)

<sup>52</sup>A/C Pipe Producers Association, *Recommended Work Practices for A/C Pipe* (Arlington, Virginia: The Association, 1977); American Water Works Association, *Work Practices for Asbestos-Cement Pipe*, Manual 16 (Denver, Colorado: AWWA, 1978); Asbestos Information Association/North America, *Recommended Work Practices for Field Fabrication of Asbestos-Cement Sheet* (Arlington, Virginia: AIA/NA, 1980); and Bragg, *The Technical Feasibility and Cost of Controlling Workplace Exposure to Asbestos Fibres*, p. 86.

**Table 10.4**  
**Exposure Levels in Construction: Fibres per Cubic Centimetre**

<b>Use of asbestos-cement sheet and pipes</b>	<b>U.K. Data</b>	<b>AIA/NA Data</b>
Machine drilling	2	1.65
Hand sawing	2-4	0.11
Machine sawing without effective local exhaust ventilation (i) jig saw	2-10	
(ii) circular saw	10-20	20
Machine sawing with effective exhaust ventilation	2	
Compression shearing of pipe		0.2
<b>Use of asbestos insulation board</b>	<b>U.K. Data</b>	<b>Johns-Manville Data</b>
Drilling vertical structures e.g., column casing	2-5	
Drilling overhead e.g., suspended ceilings	4-10	3.3 — no control 0.1 — with shroud
Sanding and surfforming	6-20	
Scribing and breaking	1-5	0.8
Hand sawing	5-12	0.1 — no collection (but dust on floor possible cleanup problem)
Machine sawing without effective local exhaust ventilation (i) jig saw	5-20	2.1
(ii) circular saw	20	3.0 — with control
	upwards	
Unloading deliveries of board (short-term sampling)		
(i) cut pieces	5-15	
(ii) manufacturers standard size sheets	1-5	

**SOURCES:** Adapted from: Gordon M. Bragg, *The Technical Feasibility and Cost of Controlling Workplace Exposure to Asbestos Fibres*, Royal Commission on Asbestos Study Series, no. 7 (Toronto: Royal Commission on Asbestos, 1982), Table 3.1, p. 45.

The sources used by Bragg were:

For the U.K. data: U.K., Health and Safety Executive, "Technical Data Note 42: Probable Asbestos Dust Concentrations at Construction Projects," in *Precautions in the Use of Asbestos in the Construction Industry*, a report by the sub-committee of the Joint Advisory Committee on Safety and Health in the Construction Industries (London: Her Majesty's Stationery Office, 1974), p. 8.

For the AIA/NA data: Asbestos Information Association/North America and Association of Asbestos-Cement Pipe Producers, "Recommended Standard for Occupational Asbestos Exposure in Construction and Other Non-Fixed Work Operations," 7 February 1980. (Mimeographed.)

For the Johns-Manville data: Johns-Manville, Research and Development Center, "Evaluation of Tools for the Dust-Free Fabrication of Asbestos Cement," Report no. E411-1050-S1, 9 June 1978; and Report no. E411-1050-S2, 2 August 1978. (Mimeographed.)

If the precautions which we have recommended for asbestos-cement products and for asbestos insulation board are to be effective, it is important that workers know when they are working with these products. It is therefore necessary that these products be labelled, so that purchasers and workers can readily identify them as asbestos-containing materials. We recommend such labelling requirements in Chapter 11, Recommendation 11.1.

Other construction products currently in use that contain asbestos include roof coatings, roofing, caulking, and flooring. The asbestos in the first three product categories is generally saturated with asphalt or tar so that there is virtually no possibility of fibres being released during normal installation and use. The fibres are sufficiently tightly bound that we presume that work with these products would not create a hazardous work area.

In the case of floor tiles, normal installation and use should not cause fibre release. However, Sebastien, Bignon, and Martin have reported an isolated instance in which airborne asbestos fibre levels above background levels were ascribed to severe wear of vinyl-asbestos floor tiles, rather than to damaged friable asbestos-containing materials.<sup>53</sup> The fibre levels observed (8, 21, 25, and 170 ng/m<sup>3</sup>) were similar to those in buildings containing sprayed asbestos insulation in good condition. All fibres were less than 3 microns in length and therefore shorter than the fibres we found in Chapter 5 to be most hazardous. The researchers, after a diligent search, could find no asbestos fibre source other than the floor tiles.

The notion that above-background asbestos fibre levels could be caused by vinyl-asbestos floor tile is surprising; the fibres in vinyl-asbestos tiles tend to be tightly bound, and most observers have concluded that the release of respirable fibres from such tiles is most unlikely. However, even if we accept the inference drawn by Sebastien, Bignon, and Martin, the fibre levels generated by severely worn floor tiles were no higher than those found in buildings with sprayed insulation in good condition. We note, performing the conversions suggested in Chapter 9, Section D, that even 170 ng/m<sup>3</sup> would yield only 0.005 f/cc. Accordingly, on the available evidence, we conclude that asbestos floor tiles do not present a hazard to building occupants, or workers, with the sole exception of sanding during removal.

Asbestos floor tiles should not be sanded during removal without "Precautions A," described in Recommendation 10.14, being taken. This should be required by regulation: see Recommendation 10.18, which addresses types of work in a hazardous work area not otherwise specifically

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<sup>53</sup>P. Sebastien, J. Bignon, and M. Martin, "Indoor Airborne Asbestos Pollution: From the Ceiling and the Floor," *Science* 216 (25 June 1982): 1412.

covered by our recommendations for work procedures on construction projects and on maintenance and custodial projects. We note that while suppliers of asbestos floor tile usually recommend against sanding, their recommendation may not be generally followed in practice.

Sheet or rolled flooring, as distinct from vinyl-asbestos tiles, often comes with a backing of chrysotile asbestos. Since the backing is under the flooring, no fibres can be released during use. However, when the flooring is removed, some of the asbestos backing usually remains behind on the floor. Suppliers recommend that this backing be removed by wetting and scraping by hand. Sanding is not recommended as it would cause substantial airborne asbestos concentrations. Again, it is suspected that in practice the backing is often removed by sanding. We note that sanding asbestos-containing backing of sheet or rolled flooring would call for the application of "Precautions A" described in Recommendation 10.14: see Recommendation 10.18.

Certain pipe insulation materials containing asbestos are still sold in Ontario. These are discussed in Chapter 9, Section B.2, and include asbestos-insulating cement, corrugated asbestos paper, asbestos tape, and asbestos rope lagging. We are recommending that the application of these products be prohibited: see Recommendation 9.3. In any event, these products are not widely used today.<sup>54</sup>

### D.3 Asbestos Control Work Supervisors and Inspectors

It is clear from Pinchin's description of problems encountered in stripping insulation from a pipe and boiler that skill and practice are important ingredients in performing asbestos control work which maintains fibre levels at or below the newly adopted Ontario workplace standard.<sup>55</sup> According to Pinchin, over the course of one removal project, careful attention to work practices reduced fibre levels by a factor of 10.

A number of submissions to this Commission described poorly executed control projects, emphasizing the importance of ensuring that proper work procedures are followed on asbestos control projects.<sup>56</sup> Mr.

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<sup>54</sup>Telephone communication between Mr. Ian Dewar, Dewar Insulations Inc. and Royal Commission on Asbestos Staff, 25 March 1983.

<sup>55</sup>Pinchin, *Asbestos in Buildings*, pp. 7.21-7.25.

<sup>56</sup>RCA Transcript, Submission by Dr. Brian Gibson on behalf of the Toronto Occupational Health Resource Committee, 18 February 1981, Volume no. 3, p. 100; RCA Transcript, Submission by Mr. Bob DeMatteo on behalf of the Ontario Public Service Employees Union, 18 February 1981, Volume no. 3, p. 188; and RCA Transcript, Submission by Mr. Joe Duffy on behalf of the Provincial Building and Construction Trades Council of Ontario, 8 June 1981, Volume no. 7, p. 7.

John Donaldson, speaking on behalf of the International Association of Bridge, Structural and Ornamental Iron Workers, Local 721, in describing a removal project at the Toronto International Airport in 1977, related many examples of work practices which allegedly exposed workers to unnecessarily high asbestos fibre levels.<sup>57</sup> His account of this removal project underscores the inadequacy of spot checks by Ministry of Labour inspectors as the only means of evaluating asbestos-related risks and of verifying that proper control procedures are being carried out.

We note that a draft regulation, "Asbestos Insulation and Coating," was prepared in the United Kingdom in 1981. The proposed regulation would prohibit certain categories of employers and self-employed persons from carrying out work involving asbestos insulation and asbestos coating without a validated licence to do so. The U.K. Health and Safety Commission would be empowered to set the requirements for such licences.<sup>58</sup>

Notwithstanding that procedures for controlling exposure to asbestos may be spelled out in some detail in regulations, informed and adaptive responses to a wide variety of work situations will require specialized knowledge. In order to ensure that this knowledge is available on every asbestos control work site, asbestos control work should be supervised by properly qualified asbestos control work supervisors. This could be provided for by way of regulation under the *Occupational Health and Safety Act*, by way of amendment to that Act, or by way of regulation pursuant to an amendment to the regulation-making power under that Act. We accordingly recommend that:

*10.24 The Ministry of Labour should take steps to institute a register of individuals certified as competent to supervise the enclosure, encapsulation, or removal of asbestos-containing sprayed insulation and pipe and boiler insulation. Certificates of competence should be awarded by the Ministry of Labour; incompetence should result in the certificate being revoked.*

We further recommend that:

*10.25 The Ministry of Labour should take steps to require that no asbestos enclosure, encapsulation, or removal may take place without being supervised by a registered work supervisor. The Ministry of Labour should determine what exceptions to this requirement should be made for small jobs.*

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<sup>57</sup>RCA Transcript, Submission by Mr. John Donaldson on behalf of the International Association of Bridge, Structural and Ornamental Iron Workers, Local 721, 18 February 1981, Volume no. 3, pp. 4-19.

<sup>58</sup>In 1982, the Health and Safety Commission decided to adopt these measures, but, as of the summer of 1983, they did not yet have the force of law.



## **Part V**

### **Asbestos Elsewhere**



## **Chapter 11 Asbestos in the Environment**

### **A. Asbestos in Construction and Consumer Products**

#### **A.1 Use and Exposure**

Asbestos is commonly found in consumer products. The Asbestos Information Association/North America has suggested that there are over 3,000 different end uses for raw asbestos fibre, many of which find their way into the home.<sup>1</sup> Asbestos may be contained in consumer products as diverse as ironing board covers, oven gloves, toasters, broilers, ovens, refrigerators, and clothes washers and dryers. As well, building materials that are primarily installed by tradesmen, such as asbestos floor tiles and roofing, asbestos-cement sheet, and asbestos-textured paints, may be handled and installed by consumers in a domestic context.

In written submissions made to this Commission, concern was expressed over the potential release and subsequent inhalation of asbestos fibres contained in various consumer products. The Consumers' Association of Canada (CAC) has called for the reduction or elimination of asbestos in consumer and other products, as technology permits.<sup>2</sup>

The degree of hazard posed by an asbestos-containing consumer product is dependent upon the matrix in which the fibre is contained and the frequency and manner of use of the consumer product. This issue was considered by the Consumer Product Safety Commission (CPSC) in the United States. A CPSC memorandum described the responses to a general order issued in December 1980, requiring manufacturers and importers of sixteen categories of products to provide information on the asbestos

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<sup>1</sup>Asbestos Information Association/North America [information pamphlet] (Arlington, Virginia: AIA/NA, 1980).

<sup>2</sup>Consumers' Association of Canada, Written submission to the Royal Commission on Asbestos, #17, January 1981, p. 2.

materials used in their products.<sup>3</sup> The memorandum reviewed the information submitted and raised some concern regarding the release of asbestos fibres contained in only a few products, including clothes washers and dryers, and dishwashers. Although asbestos paper used as a thermal barrier in clothes dryers and dishwashers may emit asbestos fibres as a consequence of mechanical vibration, the CPSC staff concluded that it was unlikely that the asbestos components in these product categories presented a significant health risk. As well, the memorandum referred to evidence that the use of these asbestos components has been discontinued. The CPSC expressed concern “. . . that the asbestos-containing brake lining of some clothes washers is subject to sufficient mechanical stress to release asbestos fibers during use.” However, a non-asbestos substitute for these brake linings was actively being sought by manufacturers of these appliances.<sup>4</sup>

The findings presented in an earlier report commissioned by the CPSC were consistent with the conclusions drawn from the information submitted in response to the general order.<sup>5</sup> That is, of the 120 different asbestos-containing products evaluated in the earlier report, few seemed to emit asbestos fibres in concentrations which could raise the possibility of any health effect.

Hand-held hairdryers are the only appliances that have been tested in Canada for release of asbestos fibres. Tests undertaken by the Health Protection Branch of Health and Welfare Canada in 1979 revealed that asbestos was released by hand-held hairdryers in concentrations equivalent to normal background levels in the ambient air of Canadian cities.<sup>6</sup> Although the Branch concluded that no health risk was presented by the use of hairdryers containing asbestos liners, the Branch nonetheless recommended that asbestos use in these appliances be discontinued.

The use of asbestos-containing construction products, by householders or by construction workers, including asbestos-cement pipe and sheet, asbestos floor tiles and roofing, and asbestos-textured paints, might involve asbestos fibre release during sawing, cutting, application, or removal. For example, Rohl et al. have reported on the domestic uses of

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<sup>3</sup>U.S., Consumer Product Safety Commission, Memorandum from Rory Sean Fausett, Program Manager, Chemical Hazards Program to the CPSC, Subject, Asbestos General Order, 8 January 1982. (Mimeographed.)

<sup>4</sup>Ibid., pp. 4-5.

<sup>5</sup>A.T. Kearney, Inc., *Review of Asbestos Use in Consumer Products: Final Report*, prepared for the U.S. Consumer Product Safety Commission (Washington, D.C.: U.S. Consumer Product Safety Commission, HIA/Economic Analysis, April 1978).

<sup>6</sup>Canada, Department of National Health and Welfare, Health Protection Branch, Environmental Health Directorate, “Preliminary Study on the Possible Release of Asbestos Fibres During the Operation of Hand-Held Hair Dryers,” report prepared by Jean-C. Méranter and Albert B.C. Davey ([Ottawa], May 1979.)

spackling, patching, and taping compounds, many of which contained chrysotile asbestos as a reinforcing agent prior to prohibitions in both Canada and the United States.<sup>7</sup> The fibres become airborne during mixing and sanding of the compounds. The researchers found levels of exposure during home repair work involving the use of such compounds to be as much as 7 to 12 times greater than the 5 fibres per cubic centimetre (f/cc) occupational standard then in force in the United States. Furthermore, the fibres were found to remain suspended after mixing and to move into other rooms.

The U.S. National Institute for Occupational Safety and Health (NIOSH), at the request of the CPSC, examined asbestos paper used to insulate hot water pipes, heat ducts, and walls that are in close proximity to stoves and ovens to ascertain the amount of fibre release from these sources. The NIOSH study found that "... if folded, torn, or cut, the product released fibers of asbestos to an extent that could produce airborne levels in excess of the NIOSH recommended average level for occupational exposure."<sup>8</sup> This recommended level is 0.1 f/cc, but has not been implemented. It should be noted that the fibre levels released by working with asbestos paper are two orders of magnitude less than the fibre levels Rohl found during the sanding and mixing of drywall compounds.

The major concern with the use of asbestos-containing construction products relates to exposures experienced during application and handling by construction workers. In contrast to construction workers, householders will likely perform such work only infrequently and will generate low cumulative exposure levels. However, considering the relatively intense exposures experienced during improper application of some of these products, and the potential for young children to be exposed to resulting dust, we believe that consumers, as well as construction workers, should be protected by various measures ranging from outright prohibition of certain asbestos-containing products to information about risks and appropriate work practices associated with other products.

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<sup>7</sup> Arthur N. Rohl et al., "Exposure to Asbestos in the Use of Consumer Spackling, Patching, and Taping Compounds," *Science* 189 (15 August 1975): 551-553.

<sup>8</sup> "Commission Authorizes Ban on Asbestos Paper Direct Sales to Consumers and Home Contractors," in *News from U.S. CPSC* (Washington, D.C.: U.S. Consumer Product Safety Commission, 11 April 1980), p. 2.

## A.2 Current Regulations

### (a) The United States

The *Consumer Product Safety Act*<sup>9</sup> allows the Consumer Product Safety Commission to promulgate consumer product safety standards,<sup>10</sup> to ban consumer products,<sup>11</sup> and to create consumer product safety rules and accompanying product certification and labelling procedures.<sup>12</sup> In December 1977, the Commission issued a ban on consumer patching compounds containing respirable free-form asbestos<sup>13</sup> and a ban on artificial emberizing materials (ash and embers) containing respirable free-form asbestos for consumer use.<sup>14</sup> Under the federal *Hazardous Substances Act*,<sup>15</sup> administered by the CPSC, a ban was placed on general-use garments containing asbestos, except those which have a *bona fide* application for thermal protection and which are constructed so that the fibres will not become airborne.<sup>16</sup>

### (b) The United Kingdom

The *Health and Safety at Work Act, 1974*, provides that manufacturers, designers, importers, and suppliers of goods must ensure, so far as is reasonably practicable, that the article is so designed and constructed as to be safe without risks to health when properly used.<sup>17</sup> A voluntary programme of product labelling was introduced in 1976 and applies to all U.K. manufactured asbestos-containing products and waste which could, under foreseeable circumstances, cause a danger to health through release of asbestos. Certain consumer goods were specifically designated for inclusion in the labelling programme.<sup>18</sup>

The European Economic Community agreed to marketing and use directives for asbestos products in June of 1983. These directives incorporate a labelling programme.<sup>19</sup>

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<sup>9</sup> 15 U.S.C.A. § 2051 et seq.

<sup>10</sup> Ibid., § 2056.

<sup>11</sup> Ibid., § 2057.

<sup>12</sup> Ibid., § 2063.

<sup>13</sup> 16 CFR Part 1304, 42 FR 63362, 15 December 1977.

<sup>14</sup> 16 CFR Part 1305.

<sup>15</sup> 15 U.S.C.A. § 2055 et seq.

<sup>16</sup> 15 CFR 1500.17.

<sup>17</sup> 22 & 23 Eliz. II, c. 37, par. 6(1)(a).

<sup>18</sup> Included were oven gloves, oven door replacement seals, ironing board replacement rests, simmering pads, wall plugging compounds, brake linings, insulation board, and cement sheet.

<sup>19</sup> Telephone communication between Mr. Stanley King, U.K. Health and Safety Executive and Royal Commission on Asbestos Staff, 29 June 1983.

### (c) Canada — Federal Provisions

The *Hazardous Products Act* prohibits the advertising, selling, or importing of specific hazardous products.<sup>20</sup> Such prohibitions have been imposed on asbestos garments (except those specifically designed for thermal protection and constructed in a manner that ensures that asbestos fibres will not be released);<sup>21</sup> asbestos-containing educational or play products for use by children where they are made in such a way that asbestos may become separated from the products; asbestos material used in modelling and sculpture, drywall joint cements and patching compounds made in such a way that airborne asbestos may become separated from the products during preparation, application, repair, or removal; and products used to simulate ashes and embers.<sup>22</sup> The Canadian regulations appear to cover virtually the same articles as the U.S. regulations.

### (d) Canada — The Provinces

While provincial legislative jurisdiction appears to be broad enough to establish hazard standards for asbestos-containing consumer products, the provinces have generally not acted on this jurisdiction to date.<sup>23</sup>

## A.3 Recommendations

Although a number of products which presented significant potential for fibre release have been removed from the market by the federal Department of Consumer and Corporate Affairs, we believe that there is a need for a more structured response to the hazards of asbestos-containing construction and consumer products. In fact, the response that has been forthcoming has been erratic. Thus, the voluntary removal of asbestos liners from hairdryers was secured by the federal government in spite of scientific data indicating the absence of any true hazard, while free-form asbestos is currently available at hardware stores throughout the country.<sup>24</sup>

There is little evidence on health risks posed by asbestos-containing products. However, we do know that loose asbestos is patently dusty, while, on the other hand, products in which the asbestos component is thoroughly sealed off or encapsulated are not likely to release asbestos fibres under

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<sup>20</sup> R.S.C. 1970, c. H-3.

<sup>21</sup> S.O.R./73-402.

<sup>22</sup> S.O.R./76-0342, as amended by S.O.R./80-288.

<sup>23</sup> Robert T. Franson et al., *Canadian Law and the Control of Exposure to Hazards*, Science Council of Canada Background Study, no. 39 (Ottawa: Science Council of Canada, October 1977).

<sup>24</sup> Canada, Department of National Health and Welfare, "Preliminary Study on the Possible Release of Asbestos Fibres During the Operation of Hand-Held Hair Dryers."

foreseeable use. Between these two categories of asbestos-containing products are a number of products which could release asbestos dust. Regulation of asbestos-containing products should accordingly distinguish among these three categories of goods. Since both the federal and the provincial governments have legislative power in this area, intergovernmental co-operation is needed to avoid over-regulation and duplication. We therefore recommend that:

*11.1 The Government of Ontario should take steps, either through federal-provincial collaboration or by having recourse to provincial legislative jurisdiction, towards the regulation of asbestos-containing consumer and construction products in accordance with the following scheme:*

*Products containing asbestos should be classified into one of three categories:*

*Category One:*

*This category would embrace loose asbestos which, during normal use or handling, is likely to release asbestos fibres in significant concentrations. An example of this is loose-fill asbestos insulation.*

*Category Two:*

*This category would embrace products containing asbestos which possess the potential to release asbestos fibres in significant concentrations in the event of misuse, improper handling, manipulation such as cutting or sanding, or as a result of product degradation. Products in this category would include asbestos-cement sheet; and asbestos gloves, simmering pads, and ironing board replacement sheets.*

*Category Three:*

*This category would embrace products containing asbestos which is sealed off or encapsulated so that the release of asbestos fibres is unlikely under foreseeable use. Products in this category would include most appliances which contain asbestos insulation and molded plastic products containing asbestos filler.*

We further recommend that:

*11.2 The following regulatory actions should be taken with respect to Categories One and Two:*

- (i) The manufacture, sale, and use of products in Category One, other than essential products for which there is no adequate*

*substitute, should be prohibited in Ontario, unless the product is exclusively for the use of a manufacturing enterprise governed by the existing Regulation Respecting Asbestos.*

- (ii) *All products in Category One, the manufacture, sale, or use of which are not prohibited in Ontario, and all products in Category Two, should be labelled with the following warning:  
“Caution — Contains Asbestos — Breathing Asbestos May Be Dangerous to Your Health — Consult Pamphlet Available From Vendor For Proper Use.”*
- (iii) *All purchasers of construction materials labelled in accordance with (ii) above should be provided with a pamphlet outlining the nature of the hazard posed by the product and the appropriate precautions to be taken in connection with the product.*

Finally, we recommend that:

*11.3 Products in Category Three should not be subject to regulation.*

## **B. Asbestos in Water, Food, Beverages, and Drugs**

### **B.1 Introduction**

In Chapter 5 we discuss the evidence regarding health effects of eating or drinking asbestos fibres. There we conclude that the evidence fails to indicate any increased risk of alimentary tract tumours following the direct ingestion of asbestos fibres. This conclusion is based on two sources of evidence. First, most animal evidence shows that feeding asbestos to animals does not cause an increase in gastrointestinal cancer, and in fact does not cause asbestos fibres to be lodged in the gastrointestinal tract. If the fibres are not retained in the gastrointestinal tract, as they are in the lungs, it is highly unlikely that they will cause disease. Second, epidemiological studies of human health related to asbestos levels in drinking water have generally found no health effects from high asbestos levels. In a Canadian study, Toft et al. analyzed water-borne asbestos levels and mortality rates in 71 municipalities across Canada.<sup>25</sup> The researchers concluded that there was not a significant relationship between water-borne asbestos levels and gastrointestinal cancer. A study by Conforti et al. was the only one of more than a half-dozen studies of health and asbestos in drinking water that suggested any such relationship, and even there the sug-

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<sup>25</sup>P. Toft et al., “Asbestos and Drinking Water in Canada,” *The Science of the Total Environment* 18 (1981): 77–89.

gested relationship was weak.<sup>26</sup> Only a fraction of the many analyses performed by Conforti et al. pointed to a correlation of asbestos with cancer, and the authors noted that confounding factors such as smoking, occupation, and alcohol consumption may be important but were not allowed for in the study.

In summary, we find that oral ingestion of asbestos in concentrations currently found in water, food, or beverages in North America is not associated with any significant increase in disease. Although negative epidemiological studies cannot conclusively prove that there is no association, the populations studied have been sufficiently large that all but the smallest health effects would have been detected. For their part, the bulk of the animal studies have shown no association between oral asbestos ingestion and gastrointestinal cancer.

We, therefore, find that there is no reason for public concern about the health effects of asbestos in water, food, and beverages. However, as the presence of asbestos in water, food, and beverages has been extensively studied, we summarize the data below.

## B.2 Asbestos in Drinking Water

The measurement of asbestos fibre concentrations in water may be performed using transmission electron microscopy (TEM). The water sample is drawn through a Nuclepore filter, which is then carbon-coated. The filter is dissolved, leaving the thin carbon-coating with embedded fibres ready for examination using a TEM. The U.S. EPA has commissioned a study, to be published by early 1984, which develops a standardized method of measurement for asbestos fibres in water. The fibre concentration is usually reported in millions of fibres of all sizes per litre of water; there is usually no separate count of fibres longer than 5 microns. A comparison of these fibre concentrations with airborne fibre concentrations would be meaningless because serious disease may arise from exposure to airborne fibres, while there is no reason for concern about the health effects of asbestos in water.

Cunningham and Pontefract's Canadian study detected levels of asbestos in tap water, melted snow, and river water ranging from 2 million to 173 million fibres per litre.<sup>27</sup> These results are shown in Table 11.1. Unfiltered tap water in a Quebec asbestos mining town contained the highest

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<sup>26</sup>Paul M. Conforti et al., "Asbestos in Drinking Water and Cancer in the San Francisco Bay Area: 1969-1974 Incidence," *Journal of Chronic Diseases* 34 (1981): 211-224.

<sup>27</sup>Hugh M. Cunningham and Roderic D. Pontefract, "Asbestos Fibres in Beverages and Drinking Water," *Nature (London)* 232 (30 July 1971): 332.

levels. River water contained more asbestos fibres than water drawn from a city filtration system and melted snow contained higher amounts than river water. Most fibres detected were below 1 micron in length.

Kay reported on asbestos fibre levels in drinking water from 21 cities in Ontario, drawing on surface waters for samples.<sup>28</sup> Samples were examined at a magnification which ranged from 25,000 to 50,000 times. As with Cunningham and Pontefract's investigation, the detected fibre levels varied widely. For instance, Kay found Ottawa's tap water to have a fibre count of 0.136 million fibres per litre, while Sarnia's count was 3.87 million fibres per litre. Kay's data are summarized in Table 11.2. Additional surveys undertaken in Metropolitan Toronto found levels of asbestos which ranged from 0.724 million to 4.06 million fibres per litre.

Health and Welfare Canada commissioned a national survey for asbestos fibres in Canadian drinking water in 1977.<sup>29</sup> The authors of the study, which was done under the auspices of the Ontario Research Foundation, relied on the U.S. EPA's preliminary interim method to evaluate the concentration and type of asbestos present in water samples. The study reported on samples from 71 locations across Canada, representing the water supplies of close to 55% of the Canadian population. Samples were obtained from the raw water source, from the water treatment plant, and from the water distribution network. The researchers concluded that amphibole asbestos was not a major contaminant of Canadian drinking water supplies. In locations where amphibole asbestos was detected, there was usually a much higher concentration of chrysotile fibres. The highest concentrations of chrysotile fibres were detected in Baie Verte, Newfoundland, and Disraeli, Quebec, at levels of up to 1,800 million fibres per litre. In Ontario, the highest levels were found in Thunder Bay, Kirkland Lake, and Hearst, with detected values of up to 3 million, 3.5 million, and 22 million fibres per litre respectively. Data from this study are shown in Table 11.3. Potable water in the 15 other locations sampled in Ontario had fibre levels below 1 million fibres per litre.

The difficulties in measuring asbestos fibre concentrations in water may be illustrated by the controversy surrounding asbestos levels in the water in Thunder Bay, Ontario, in 1975. Early in 1975, researchers at Lakehead University reported asbestos concentrations in the drinking water in that city ranging from 0.45 million fibres per litre to 14.7 million fibres

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<sup>28</sup>G.H. Kay, "Asbestos in Drinking Water," *Journal American Water Works Association* 66:9 (September 1974): 513-514.

<sup>29</sup>Eric J. Chatfield and M. Jane Dillon, *A National Survey for Asbestos Fibres in Canadian Drinking Water Supplies*, 79-EHD-34 (Ottawa: Health and Welfare Canada, Environmental Health Directorate, 1979).

**Table 11.1**  
**Asbestos Fibre Concentrations in Beverages and Water**

Sample	Source	Millions of Fibres per Litre
Beer	Canadian 1	4.3
Beer	Canadian 2	6.6
Beer	U.S.A. 1	2.0
Beer	U.S.A. 2	1.1
Sherry	Canadian	4.1
Sherry	Spanish	2.0
Sherry	South African	2.6
Port	Canadian	2.1
Vermouth	French	1.8
Vermouth	Italian	11.7
Soft drink	Ginger ale	12.2
Soft drink	Tonic water I	1.7
Soft drink	Tonic water II	1.7
Soft drink	Orange	2.5
Tap water	Ottawa, Ottawa River*	2.0
Tap water	Toronto, Lake Ontario*	4.4
Tap water	Montreal, St. Lawrence River*	2.4
Tap water	Hull, Quebec, Ottawa River**	9.5
Tap water	Beauport, Quebec, St. Lawrence River (6 km below Quebec City)**	8.1
Tap water	Drummondville, Eastern Townships, Quebec, St. François River*	2.9
Tap water	Asbestos, Eastern Townships, Quebec, Nicolet River*	5.9
Tap water	Thetford Mines, Eastern Townships, Quebec, Lac à la Truite**	172.7
Melted snow	Ottawa, top 30 cm (2-3 weeks' precipitation)	33.5
River water	Ottawa River, at Ottawa	9.5

**Notes:** \*Filtration plant used.

\*\*No filtration plant used.

**SOURCE:** Hugh M. Cunningham and Roderic D. Pontefract, "Asbestos Fibres in Beverages and Drinking Water," *Nature (London)* 232 (30 July 1971): 332.

Table 11.2  
Asbestos Fibre Concentrations in Ontario Tap Water

Sample Location	Source	Millions of Fibres per Litre	Estimated Mass Concentration, Nanograms per Litre
Toronto	Lake Ontario	1.9	0.941
Belleville	Bay of Quinte	0.533	0.937
Brantford	Grand River	0.570	1.13
Brockville*	St. Lawrence River	0.446	0.602
Chatham	Thames River	0.595	1.57
Cornwall	St. Lawrence River	2.11	0.729
Hamilton	Lake Ontario	0.694	0.154
London	Lake Huron	0.456	0.429
Niagara Falls	Niagara River	2.58	2.25
North Bay*	Trout Lake	0.384	0.104
Oshawa	Lake Ontario	0.557	0.159
Ottawa	Ottawa River	0.136	0.093
Pembroke*	Ottawa River	2.85	0.538
Peterborough	Otonabee River	1.86	3.54
Port Colborne	Welland Ship Canal	0.608	0.847
Sarnia*	Lake Huron	3.87	2.13
Sault Ste. Marie*	St. Marys River	0.248	0.141
St. Catharines	Welland Ship Canal	1.03	1.56
Sudbury*	Ramsay Lake	0.297	0.542
St. Thomas	Lake Erie	1.60	0.500
Thunder Bay*	Lake Superior	0.830	0.235
Welland	Welland Ship Canal	0.820	0.479

**Note:** \*No filtration plant used.

SOURCE: Adapted from: G.M. Kay, "Asbestos in Drinking Water," *Journal American Water Works Association* 66:9 (September 1974), Table 1, p. 514.

Table 11.3  
Summary of Asbestos Fibre Concentrations in Ontario Tap Water  
(Millions of Fibres per Litre)

City	Chrysotile			Amphibole			Water Filtration
	Raw Water Input	Treated Water Output	Distribution Network	Raw Water Input	Treated Water Output	Distribution Network	
Cochrane	*	*	0 - 0.5	*	*	0 - 0.5	Yes
Hamilton	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	Yes
Hearst	*	*	11 - 22	*	*	0 - 1.5	No
Kenora	*	*	0 - 1	*	*	0 - 0.5	No
Kingston	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	Yes
Kirkland Lake	*	*	1 - 3.5	*	*	0 - 0.5	No
London	1	0 - 0.5	0 - 1	0 - 0.5	0 - 0.5	0 - 0.5	Yes
Matachewan	0 - 0.5	1	0 - 1	0 - 0.5	0 - 0.5	0 - 0.5	No
Matheson	7.5	1	0 - 1.5	0 - 1	0 - 0.5	0 - 0.5	No
North Bay	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	No
Ottawa	4.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	Yes
Peterborough	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	Yes
Sault Ste. Marie	*	*	0 - 0.5	*	*	0 - 0.5	No
Sudbury	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	No
Thunder Bay	2	1	2 - 3	0.5	0 - 0.5	0 - 0.5	No
Tilbury	14**	0 - 0.5	0 - 0.5	0 - 7	0 - 0.5	0 - 0.5	Yes
Toronto	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	Yes
Windsor	1.5	0 - 0.5	0 - 0.5	0 - 1.5	0 - 0.5	0 - 0.5	Yes

Notes: \*Sample not analyzed.

\*\*High solids content did not permit adequate sensitivity. Result reported corresponds to 2 fibres in 20 grid squares examined.

SOURCE: Adapted from: Eric J. Chatfield and M. Jane Dillon, *A National Survey for Asbestos Fibres in Canadian Drinking Water Supplies*, 79-EHD-34 (Ottawa: Health and Welfare Canada, Environmental Health Directorate, 1979), Table 6, p. 31.

per litre.<sup>30</sup> These data were reported in Thunder Bay and led to demands for investigation and for filtration of the city water supply. Independent tests conducted for the Ministry of the Environment showed fibre concentrations of less than 1 million per litre. At a Thunder Bay City Council meeting in April 1975 it was suggested that the high fibre counts produced by Lakehead University might have been the result of laboratory or analytical errors.

Attempting to resolve the controversy, the Ontario Ministry of the Environment established an inter-laboratory study, sending samples of Thunder Bay drinking water to five Ontario laboratories, including the Ontario Research Foundation, McMaster University, the Canada Centre for Inland Waters, Health and Welfare Canada, and Lakehead University. The last two laboratories did not participate in the study. The first three laboratories did analyze the water, yielding results which were described in a report dated September 1975. The average fibre count reported by the Canada Centre for Inland Waters was 0.63 million fibres per litre; McMaster University, 8.45 million; and the Ontario Research Foundation, 0.06 million fibres per litre.<sup>31</sup> Previous studies had shown the Thunder Bay water to contain less than 1 million fibres per litre.<sup>32</sup> The report suggested that the large inter-laboratory differences in reported fibre concentrations might be attributable to differences in counting techniques and differences in the criteria used to identify asbestos fibres. The Ontario Research Foundation, which used relatively sophisticated means for determining whether fibres were asbestos or some other mineral, reported the lowest fibre count. The report concluded by recommending that standards be set for measuring asbestos fibre concentrations in water. The Ontario Research Foundation has subsequently been engaged by the U.S. Environmental Protection Agency to develop a technique to be used for measuring the asbestos in water in the United States.

Asbestos may be deposited in water supplies by natural mechanisms such as the airborne transfer of fibres from wind erosion of asbestiform mineral outcroppings. Cunningham and Pontefract discussed surveys undertaken in British Columbia and the Yukon which linked the levels of asbestos in water to ground water drainage and surface run-off in areas where there was natural exposure of asbestos-bearing bedrock.<sup>33</sup>

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<sup>30</sup>Don Smith, "University Dean of Science Urges Filtering of Water Now," *Chronicle-Journal* (Thunder Bay, Ontario), 18 April 1975, p. 1.

<sup>31</sup>Ontario, Ministry of the Environment, "An Inter-laboratory Study of Asbestiform Mineral Fibre Levels in the Water Supply of Thunder Bay, Ontario," Rexdale, Ontario, September 1975, Table 7, p. 17.

<sup>32</sup>*Ibid.*, Table 9, p. 22.

<sup>33</sup>Cunningham and Pontefract, "Asbestos Fibres in Beverages and Drinking Water," pp. 332-333.

Another possible source of fibre release into water supplies is the asbestos-cement pipe used for water distribution in sewage systems. Asbestos-cement pipes are composed of 85% Portland cement and 15% asbestos. The asbestos component contains both chrysotile and crocidolite fibres in approximately a 4 to 1 ratio.<sup>34</sup> Sometimes amosite is used in place of crocidolite. The amount of fibre release from interior wall deterioration of asbestos-cement pipe has been the subject of much investigation. Olson addressed this issue and concluded that "... water flowing through asbestos-cement pipe does not increase the level of fibre content significantly."<sup>35</sup> In contrast, Buelow, Millette, and McFarren have found that asbestos-cement pipe behaves much like other piping materials, except plastic, that are in common use for the distribution of drinking water. If aggressive conditions towards the piping material exist (measured by pH, alkalinity, and hardness), the pipe will corrode and deteriorate.<sup>36</sup>

Mah and Boatman utilized transmission and scanning electron microscopy to study the interaction between water and asbestos-cement pipe. After one month of water flow, bundles of asbestos fibres were observed on the inner surface of pipe which had originally been smooth. Additionally, aggressive water circulated for 218 days in asbestos-cement pipes exhibited an asbestos content of 3.6 million fibres per litre. Prior to the 218-day period, the asbestos content was 1.35 million fibres per litre.<sup>37</sup>

Substitutes with equivalent performance characteristics are available for asbestos-cement pipe for sewage and water distribution applications. However, for pipe diameters of 24 inches and less, the use of substitutes may not be cost competitive.<sup>38</sup>

It appears that the most important source of asbestos deposition in large cities is industrial. High concentrations of asbestos fibres in water supplies near asbestos mining and manufacturing sites may result from the disposal of industrial asbestos-containing waste. The most notable example

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<sup>34</sup>Data from Johns-Manville Canada. See also, Robert A. Clifton, "Asbestos," in *Mineral Facts and Problems*, 1980 ed. (Washington, D.C.: U.S. Department of the Interior, Bureau of Mines, 1981), pp. 1-17.

<sup>35</sup>Harold L. Olson, "Asbestos in Potable-Water Supplies," *Journal American Water Works Association* 66:9 (September 1974): 515-518.

<sup>36</sup>R.W. Buelow, J.R. Millette, and E.F. McFarren, "Field Investigation of the Performance of Asbestos-Cement Pipe Under Various Water Quality Conditions," Cincinnati, Ohio, U.S. Environmental Protection Agency, 1977.

<sup>37</sup>M. Mah and E.S. Boatman, "Scanning and Transmission Electron Microscopy of New and Used Asbestos-Cement Pipe Utilized in the Distribution of Water Supplies," in *Scanning Electron Microscopy/1978/I*, ed. O. Johari (AMF O'Hare, Illinois: SEM Inc., 1978), pp. 85-92.

<sup>38</sup>Richard A. Simonds and James L. Warden, "Substitutes for Asbestos-Cement Pipe," in *Proceedings of the National Workshop on Substitutes for Asbestos*, Arlington, Virginia: 14-16 July 1980, EPA-560/3-80-001 (Washington, D.C.: U.S. Environmental Protection Agency, 1980), p. 160.

arises from the Reserve Mining Company, mining a low grade taconite ore in Babbitt, Minnesota, which is sent to Silver Bay for refining. For every ton of pellets produced, more than 2 tons of silica waste tailings containing cummingtonite are discharged into Lake Superior. Until legal action halted the dumping of the tailings into the lake, the company disposed of 67,000 tons of waste per day. This allegedly caused the concentration of amphibole fibres in Duluth drinking water to rise to between 1 million and 644 million fibres per litre.<sup>39</sup> As well, it was asserted in studies presented during litigation that effluent asbestos particles could move several hundred miles.<sup>40</sup>

We are not aware of asbestos wastes in Ontario being discharged into fresh water lakes in quantities approaching those discharged by Reserve Mining. In any event, we have concluded that the evidence fails to indicate adverse health effects from asbestos fibres in water.

In the United States, the Asbestos Manufacturing Point Source Category Regulations,<sup>41</sup> promulgated under the authority of the *Federal Water Pollution Control Amendment Act* of 1972,<sup>42</sup> limit pollution discharge, including total suspended solids, pH, and chemical oxygen demand, for effluents from various asbestos sources. The Act requires that all industrial sources treat effluents by applying the *best practicable control technology* (BPT) available by July 1, 1977 and the *best available control technology economically achievable* (BAT) by July 1, 1984. The BPT and the BAT are both defined for various asbestos manufacturing concerns. It is not anticipated that these targets will be achieved.

While the U.S. Food and Drug Administration has statutory authority to protect the public from unsafe hazards, no regulations governing levels of asbestos in water have been passed.

In the United Kingdom, the *Water Act, 1973*, requires local authorities to supply "wholesome" water.<sup>43</sup> The Model Water Byelaws, 1966, promulgated under this Act, prohibit allowing materials which can cause contamination to come into contact with water.

In Canada, the federal government has not established standards regulating asbestos-containing effluents. Most provinces have enacted water quality legislation. In most cases, these statutes contain general prohibitions preventing the deposit of substances in water which degrade water quality.

<sup>39</sup>R.W. Durham and Thomas W.S. Pang, *Asbestos Fibers in Lake Superior*, American Society for Testing and Materials: Special Technical Publications, no. 573 (Philadelphia: ASTM, 1975).

<sup>40</sup>*U.S. v. Reserve Mining*, 380 F. Supp. 11; 6 ERC 1657 at 1669 (1974).

<sup>41</sup>39 FR 7526, 26 February 1974.

<sup>42</sup>33 U.S.C.A. § 1251.

<sup>43</sup>21 Eliz. II, c. 37, s. 11(2).

Effluent discharge into water is, in Ontario, subject to the provisions of the *Ontario Water Resources Act*, which prohibits the deposit of any material which may cause injury to any person, animal, bird, or any living thing.<sup>44</sup> However, regulations promulgated under the Act do not set specific effluent standards for asbestos. The "Ontario Drinking Water Objectives," developed by the Ministry of the Environment, state that it is not possible at present to establish a standard for asbestos levels in drinking water, in view of the lack of epidemiological data.<sup>45</sup>

In view of our conclusions set out at the beginning of this section that the evidence fails to indicate adverse health effects from oral ingestion of asbestos, we do not recommend any change in the Ministry of the Environment's present approach to asbestos in drinking water. The health evidence does not suggest a need for standards for asbestos levels in water at this time.

### B.3 Food and Beverages

Asbestos has been widely used as a component of filters employed by the food industry. Cunningham and Pontefract measured the amount of asbestos in filtrate using electron microscope methods and found these levels to be comparable to those in tap water, melted snow, and river water.<sup>46</sup> For the Canadian samples, all the asbestos identified was chrysotile, with a length less than 1 micron. The study found between 1.1 million and 6.6 million asbestos fibres per litre in Canadian and American beer and between 1.7 million and 12.2 million fibres per litre in Canadian soft drinks.

Wehman and Plantholt detected asbestos in commercial gin.<sup>47</sup> Gaudichet et al. studied asbestos fibres in 42 bottles of wine from France and abroad and found statistically significant concentrations of chrysotile asbestos in 15 bottles. Concentrations ranged from 2 million to 60 million fibres per litre with a fibre length of from 0.9 to 3.9 microns.<sup>48</sup>

In June 1977, the Consumers' Association of Canada (CAC) published findings similar to those cited above. According to tests conducted by the CAC, levels of asbestos in excess of 2 million fibres per litre could be

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<sup>44</sup>R.S.O. 1980, c. 361, ss. 14, 15(3), 16(1), and 16(3).

<sup>45</sup>Ontario, Ministry of the Environment, Water Resources Branch, "Ontario Drinking Water Objectives," Toronto, in press, 1983.

<sup>46</sup>Cunningham and Pontefract, "Asbestos Fibres in Beverages and Drinking Water," p. 332.

<sup>47</sup>Henry J. Wehman and Barbara A. Plantholt, "Asbestos Fibrils in Beverages. I. Gin," *Bulletin of Environmental Contamination and Toxicology* 11:3 (March 1974): 267-272.

<sup>48</sup>A. Gaudichet et al., "Asbestos Fibers in Wines: Relation to Filtration Process," *Journal of Toxicology and Environmental Health* 4:5-6 (September-November 1978): 853-860.

detected in foreign wines. The CAC asserted that "The presence of any asbestos in wine is unnecessary and dangerous" and recommended "... prohibition of the use of asbestos filters in preparation of any material which would find its way into the human body. . . ." <sup>49</sup>

However, the CAC study and the other beverage surveys cited above did not show that asbestos filters were responsible for the asbestos contamination in beverages and water. In order to identify the filter as a source of fibre emission, it would have been necessary to demonstrate that the asbestos levels found in water used for beverage production were significantly lower than the levels detected in the final product. However, none of the studies above presented such measurements. The Health Protection Branch of Health and Welfare Canada does not consider action restricting the use of asbestos as a filter component to be necessary on the basis that "... it does not appear that the use of asbestos component filters results in levels of asbestos fibres in the finished product above natural background levels." <sup>50</sup> We agree with this conclusion.

We note, however, that in Ontario, the Liquor Control Board (LCBO) reacted to the publication of the CAC report by issuing a directive calling for the immediate cessation of the use of asbestos filters by domestic and foreign producers of wines, spirits, and beer. <sup>51</sup>

In its submission to this Commission, A.O. Wilson Process Equipment Limited, a filter manufacturer, charged that the LCBO has enforced the directive in a fashion which imposes severe restrictions on Ontario wine producers while turning a blind eye to violations committed overseas:

Wine filtration in each and every major wine producing country of the world is, to our knowledge, using the finest filtration material available — "asbestos," and their respective products are being imported into the province of Ontario and sold through our LCBO to the public. But it's a *no no* for Ontario wineries to use this identical material to filter their wines. <sup>52</sup>

Our staff has determined that only a few samples are examined by the LCBO each year, out of millions of bottles sold and hundreds of brands listed. Although foreign manufacturers are informed of the directive, it is

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<sup>49</sup> "Test: Asbestos in Wine," *Canadian Consumer* (June 1977): 44-47.

<sup>50</sup> Sandra Glasbeek, *A Survey of Asbestos Policies in Canada with Particular Emphasis on Ontario*, Royal Commission on Asbestos Background Paper Series, no. 1 (Toronto: Royal Commission on Asbestos, 1981), p. 40.

<sup>51</sup> *Ibid.*

<sup>52</sup> A.O. Wilson Process Equipment Limited, Written submission to the Royal Commission on Asbestos, #58, 1981, p. 2.

reasonable to assume that without greater diligence in monitoring and enforcement, these overseas manufacturers will enjoy a wide degree of latitude in complying. It therefore appears that the use of asbestos filters by foreign producers continues unimpeded.

Regarding the adequacy of substitute materials, it appears that the filters containing non-asbestos substitutes, such as cellulose and glass, are equal in performance to asbestos filters, save for the removal of "haze" from liquid beverages, an important limitation. These non-asbestos filters, which can be used interchangeably with asbestos filters, are reported to cost 10 to 15% more than asbestos filters.<sup>53</sup>

Other jurisdictions have not imposed comprehensive regulations on asbestos in food and beverages. In the United States, consideration was given to regulating the use of asbestos in talc used as a food or ingestible drug ingredient, but action was deferred until further evidence on the effect of asbestos ingestion was available.

In the United Kingdom, the *Food and Drugs Act, 1955*, provides that no substance may be added to food that would render it "injurious to health."<sup>54</sup> However, with one minor exception, no regulations have been enacted which specifically address the question of asbestos in food. The one exception is in the Miscellaneous Additives in Food Regulation, 1980, which provides that asbestos should not be present in food talc.<sup>55</sup> The U.K. Advisory Committee on Asbestos rejected specific statutory control of asbestos in food, but recommended a review of information concerning the risk to health from the contamination of food and drink by asbestos. The Advisory Committee also reported the recommendation of a Food Additives and Contaminants Committee that attempts should be made to find alternative materials for asbestos filters used in the preparation of food.<sup>56</sup> Apparently, the great majority, if not all, uses of asbestos filters in the preparation of food and drink have now been phased out in the United Kingdom. This was accomplished by industry, with the encouragement of government.<sup>57</sup>

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<sup>53</sup>GCA Corporation, "Asbestos Substitute Performance Analysis," draft revised final report prepared by Nancy Krusell and David Cogley for the U.S. Environmental Protection Agency, GCA-TR-81-32-G (Bedford, Mass.: GCA Corporation, February 1982), pp. 52-63.

<sup>54</sup>4 Eliz. II, c. 16, s. 1(1).

<sup>55</sup>S.I. 1980/1834.

<sup>56</sup>U.K., Advisory Committee on Asbestos, *Asbestos — Volume 1: Final Report of the Advisory Committee* (Simpson Report), William J. Simpson, Chairman (London: Her Majesty's Stationery Office, 1979), paragraphs 260-263 and Recommendation 39, pp. 92-93; and paragraphs P23-P24, p. 95.

<sup>57</sup>Telephone communication between Mr. Stanley King and Royal Commission on Asbestos Staff, 29 June 1983.

At the federal level in Canada, the *Food and Drug Act* provides that no person shall sell an article of food that has in it a "poisonous or harmful" substance.<sup>58</sup> No regulations have been passed under this Act which would restrict the use of asbestos in the food industry.<sup>59</sup>

In most provinces, provincial public health legislation contains provisions for control over food. Food unfit for human consumption may be prohibited under such legislation. The Ontario *Public Health Act* provides that local authorities may regulate the maintenance of premises where food or beverages are being produced.<sup>60</sup> The Food Premises Regulation under the *Public Health Act* provides that premises where food is handled must be free from any condition that may be "dangerous to health."<sup>61</sup> However, the only Ontario agency to prohibit the use of asbestos in food and beverage preparation is the Liquor Control Board, which, as discussed above, has prohibited the use of asbestos filters by producers of wines, spirits, and beer.

In view of the evidence summarized above on the health effects of ingested asbestos, and in view of the fact that asbestos fibre levels in filtrate do not appear to be significantly higher than levels in drinking water, we see no need for new legislation which would specifically limit levels of asbestos in food and beverages. In the same vein, because there is no evidence that asbestos filtration of wines, spirits, and beer causes health problems or that asbestos filters raise the asbestos concentration in beverages, and because the LCBO ban on asbestos filters is not and cannot be enforced effectively against foreign producers, we recommend that:

*11.4 The Ministry of Consumer and Commercial Relations should take steps to repeal the Liquor Control Board of Ontario ban on the use of asbestos filters.*

## B.4 Drugs

Drugs which are injected directly into the body should be considered as posing potentially different concerns than do materials which are inhaled or ingested. Nicholson, Maggiore, and Selikoff examined samples of parenteral (i.e., injectable) drugs in order to determine if they contained asbestos fibre concentrations greater than those in distilled water used in reconstitution. One-third of the samples from two sets of 17 widely used parenteral drugs were found to have levels of chrysotile in excess of those found in

<sup>58</sup> R.S.C. 1970, c. F-27, s. 4(a).

<sup>59</sup> Food and Drug Regulations, CRC, Vol. VIII, c. 870, p. 5963.

<sup>60</sup> R.S.O. 1980, c. 409, s. 9, pars. 20, 21, 38, 39.

<sup>61</sup> R.R.O. 1980, Reg. 840, s. 12(a)(i).

distilled water. The researchers linked the chrysotile contamination to the use of chrysotile-containing filters in the manufacture of drugs.<sup>62</sup>

Selikoff and Lee have reported on a follow-up study undertaken in 1974 to determine whether contamination was a continuing problem with injectable drugs and whether it occurred in oral drugs. Of the 49 parenteral drugs sampled, 8 were found to have concentrations of asbestos at least 10 times greater than the average background levels in terms of both number and mass of fibres present. None of the oral drugs showed significantly high concentrations of asbestos.<sup>63</sup>

In the United States, a study was undertaken on the carcinogenic effects of intravenous injection of small fibres of chrysotile asbestos into rats and mice. The Research Project Summary concluded as follows:

The studies have demonstrated that by the intravenous route the administration of fairly large doses of chrysotile asbestos to standard strains of mice and rats on an acute and subacute basis can be tolerated, and have little effect on survival rate. At large doses, up to about  $1.6 \times 10^{10}$  fibers/kg, over a period of 4 weeks, no carcinogenic effects were demonstrated in rats when studied for a lifetime. On the other hand, whereas mice survived well, there was evidence of carcinogenicity that was dose related and time related and possibly sex related. Whereas there were not enough animals on test to demonstrate a "no effect" dose, there is a suggestion that this dose would be fairly high, perhaps as high as  $8 \times 10^8$  fibers/kg. Of course there is no way of extrapolating such figures from mouse to man, and man frequently has a body burden (lung) from the inhalation route. It would seem prudent to avoid exposure to chrysotile asbestos in parenteral products whenever possible, and this has been done in the FR Final Order dated March 14, 1975.<sup>64</sup>

Comparing the huge doses administered in the U.S. study to the trace asbestos found in filtered drugs leads us to conclude that the risk of cancer caused by the injection of drugs is negligible.

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<sup>62</sup>William J. Nicholson, Carl J. Maggiore, and Irving J. Selikoff, "Asbestos Contamination of Parenteral Drugs," *Science* 177:44 (14 July 1972): 171-173.

<sup>63</sup>Irving J. Selikoff and Douglas H.K. Lee, *Asbestos and Disease* (New York: Academic Press, 1978), pp. 128-130.

<sup>64</sup>U.S., Food and Drug Administration, National Center for Drugs and Biologics, Research Project Summary of FDA 223-77-3017, and prior contracts entitled "Animal Studies of Chrysotile Asbestos by the I.V. Route," prepared by International Research and Development Corporation, Mattawan, Michigan, 18 December 1980, p. 119. See also, 40 FR 11865-11869, 14 March 1975.

The U.S. Final Order of March 14, 1975, referred to above, prohibits the use of asbestos filters in the manufacture, processing, or packaging of parenteral drugs, unless it is not possible to manufacture that drug without the use of such a filter.<sup>65</sup> If use of an asbestos filter is necessary, an additional non-fibre releasing filter must be used unless it is proved that such additional filtration would compromise the safety or effectiveness of the drug.

In Canada, drugs are regulated by the federal government under the *Food and Drug Act*.<sup>66</sup> There is no regulation regarding the presence of asbestos in drugs or the use of asbestos in the manufacture of drugs.

The provinces may regulate asbestos contamination in drugs by virtue of their capacity under the Constitution to protect public health. In some provinces, specific provision is made for regulation of the quality of drugs, either through public health legislation or through legislation governing pharmaceuticals. In Ontario, the *Public Health Act* allows the Ministry of Health to control the sale of impure vaccines and serums.<sup>67</sup> We are not aware of any provincial law directed specifically at asbestos in drugs.

The Health Protection Branch of Health and Welfare Canada has informed the Commission that it is aware of only two applications in which asbestos may be present in the manufacture of drugs in Canada. The Salk vaccine, administered subcutaneously, is filtered with an asbestos filter and is subsequently filtered two more times, first with a nylon filter and then with a Millipore filter. The Sabin vaccine, given orally, is filtered with an asbestos filter and then with a nylon filter. The secondary non-asbestos filters serve to reduce the asbestos content in the drugs. Manufacturers of these drugs are currently attempting safely to eliminate the use of asbestos filters; this may be a few years away.<sup>68</sup>

We see no need for regulatory action to reduce the existing use of asbestos filters in parenteral drugs in Canada.

## C. Asbestos in the Ambient Air

### C.1 Measurement

Measuring asbestos fibre concentrations in the ambient air, like

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<sup>65</sup>21 CFR Part 133.

<sup>66</sup>R.S.C. 1970, c. F-27.

<sup>67</sup>R.S.O. 1980, c. 409, s. 7(c).

<sup>68</sup>Telephone communication between Dr. John Furesz, Director, Bureau of Biologic Drugs, Health Protection Branch, Health and Welfare Canada and Royal Commission on Asbestos Staff, 16 May 1983.

measuring such concentrations in buildings, is difficult because the asbestos fibre concentrations are very low and because air sampling filters may collect a substantial amount of non-asbestos particles and fibres which must be differentiated from asbestos. In Chapter 9, Section C we discuss methods for measuring asbestos in the ambient air and in buildings and problems associated with those methods, and we reach the following conclusions. Optical microscope analysis of membrane filters, widely used for measuring fibre levels in the workplace, is not useful for measuring low concentrations of asbestos fibres, since ambient concentrations are often below the detection limit of 0.1 f/cc and because the optical microscope cannot distinguish between asbestos and non-asbestos fibres. Accurate measurement requires the use of an electron microscope, preferably a transmission electron microscope (TEM).

The TEM is used to count and identify fibres in a sample, after which the results may be reported either in terms of fibres per cubic centimetre (f/cc) or in terms of the mass of asbestos, measured in nanograms per cubic metre (ng/m<sup>3</sup>), or both. If only the mass data are reported, the process of attempting to estimate from those data the number of fibres per cubic centimetre is fraught with problems. (See Chapter 9, Section D.) Nonetheless, such attempts provide the only means of comparing TEM mass data to the data available on asbestos fibre levels in the workplace, since these latter data are generally presented in terms of fibres per cubic centimetre.

Because the TEM can resolve smaller objects than can the optical microscope, the TEM will make it possible to detect more fibres in a given air sample than would an optical microscope applied to the same sample. As a rough approximation, the TEM would detect 10 times as many fibres longer than 5 microns as would an optical microscope. Thus, TEM counts of fibres longer than 5 microns may be divided by 10 to determine approximately how many fibres might have been counted by the optical microscope, which will be referred to hereafter as the "optical microscope equivalent" of the TEM fibre count.

Finally, a single standardized method of measuring and analyzing ambient air samples has not yet been developed. Thus, it is difficult to compare measurements taken by different researchers and difficult to interpret the results that are available.

It is interesting to review the Ontario ambient asbestos guideline in the light of these measurement problems. The Ontario Ministry of the Environment's Air Resources Branch has adopted a guideline which sets out a 24-hour ambient air objective of 0.04 f/cc over 5 microns in length. The Ministry usually tests for compliance using the TEM, although the Ministry

would consider using another sort of microscope if it were shown to be equally accurate.<sup>69</sup>

At the time this ambient air guideline was developed, the occupational exposure standard was 2 f/cc longer than 5 microns measured by the optical microscope. The work week is approximately 40 hours, while exposure to ambient air could be continuous, or 168 hours per week. Thus, to maintain the same cumulative exposure, the environmental standard would have to be less than one-fourth the workplace standard, 0.476 f/cc measured optically. Because environmental exposure is involuntary and uninformed, and may affect the infirm as well as the healthy, a lower exposure was deemed appropriate, so the exposure was divided by 10. Rounding this downward yielded the 0.04 f/cc ambient standard. However, compliance with the environmental guideline requires use of the TEM, so a measurement of 0.04 f/cc by TEM might be equivalent to approximately 0.004 f/cc measured by the optical microscope. It does not appear that this greater resolution of the TEM was considered in setting the Ontario environmental guideline, with the result that the guideline may provide an order of magnitude more protection than was contemplated. Exposures that comply with the environmental guidelines may thus be approximately 1/250 of the chrysotile exposure allowed by the recently adopted workplace control limit. However, as noted above, no single measurement methodology has been promulgated for applying this guideline. The Ministry itself uses TEM, and this of course is appropriate, while the use of optical microscope methods is completely inappropriate.

## C.2 Airborne Asbestos Concentrations

Asbestos fibre concentrations in the air have been studied in locations outside Ontario. Chapter 9, Table 9.4 summarizes air monitoring data in buildings and outdoors. Sebastien's study of air quality in outdoor locations in Paris, using electron microscope techniques, found average mass concentrations of 0.96 ng/m<sup>3</sup>, with 99% of all observations at or less than 7 ng/m<sup>3</sup>. Sebastien did not report the fibre count. Nicholson studied ambient asbestos fibre concentrations in the outdoor air in New York City, using the TEM and a preparation technique called the "rub-out method." Eighty-three percent of Nicholson's observations were at or below 20 ng/m<sup>3</sup>, and 96% were less than 50 ng/m<sup>3</sup>. In Chapter 9 we estimate the optical fibre count that might be implied by these mass measurements and thereby equate Sebastien's 7 ng/m<sup>3</sup> to 0.0002 f/cc measured optically, while Nicholson's 20 ng/m<sup>3</sup> is equivalent to 0.0006 f/cc measured optically. We

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<sup>69</sup>Telephone communication between Mr. Bruce Martin, Air Resources Branch, Ontario Ministry of the Environment and Royal Commission on Asbestos Staff, 8 July 1983.

conclude that in the outdoor air it would be quite unusual to observe more than the optical microscope equivalent of 0.001 f/cc longer than 5 microns.

Selikoff, Nicholson, and Langer found concentrations of 10 to 50 ng/m<sup>3</sup> of chrysotile in the air of New York City in an early study published in 1972.<sup>70</sup> Lanting and den Boeft used the indirect preparation method and TEM analysis to determine asbestos fibre concentrations in industrial and rural towns in Holland.<sup>71</sup> They found, in large industrial towns, levels of 0.5 to 2.0 ng/m<sup>3</sup> and in rural towns, levels of 0.1 to 0.5 ng/m<sup>3</sup>. The fibre concentrations were higher in a tunnel carrying heavy traffic, a result the authors attributed to dust from brake linings. Bruckman and Rubino reported that ambient chrysotile asbestos levels were generally less than 10 ng/m<sup>3</sup> in both urban and rural locations in Connecticut.<sup>72</sup> However, measurements conducted near highway toll plazas indicated that levels higher than 10 ng/m<sup>3</sup> occurred, and it was concluded that brake lining wear was responsible.

In 1975 and 1976, the Ontario Ministry of the Environment surveyed the asbestos fibre concentrations in the air at a number of locations in the province.<sup>73</sup> The survey report began by stating: "This program was not designed as an air quality survey, but rather it was an attempt to acquire knowledge of the character of the sampled asbestiform fibres from various sources/sites and to get an indication of present asbestos concentrations in Ontario." Air samples were drawn through a Nuclepore filter, the filter was washed ultrasonically in water, and a portion of that water was transferred to a TEM grid for fibre counting. Any fibre with a 3 to 1 length to diameter ratio was considered to be "asbestiform." Among these asbestiform fibres, chrysotile and the amphiboles were identified by morphology, selected area electron diffraction, or energy dispersive x-ray analysis.

The 1975 survey of 7 areas, taking several samples in each area, contained no area with median sample concentrations of fibres longer than 5 microns greater than 0.01 f/cc. In fact, the median count in each area of fibres longer than 5 microns was usually zero or non-detectable. The count of fibres longer than 5 microns in any single sample, if not zero or non-detectable, ranged as high as 0.054 f/cc. The number of fibres of all lengths

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<sup>70</sup>Irving J. Selikoff, William J. Nicholson, and Arthur M. Langer, "Asbestos Air Pollution," *Archives of Environmental Health* 25:1 (July 1972): 1-13.

<sup>71</sup>R.W. Lanting and J. den Boeft, *Atmospheric Pollution by Asbestos Fibres*, Report no. G908 (Delft, Holland: Instituut voor Milieuhygiene en Gezondheidstechniek, T.N.O., 1979).

<sup>72</sup>Leonard Bruckman and Robert A. Rubino, "Asbestos: Rationale Behind a Proposed Air Quality Standard," *Journal of the Air Pollution Control Association* 25:12 (December 1975): 1207.

<sup>73</sup>Ontario, Ministry of the Environment, Air Resources Branch, "Asbestos as a Hazardous Contaminant, Progress Report II; Asbestos Ambient Air Monitoring Survey," Report no. ARB-TDA-20-76, Toronto, February 1976.

was considerably greater than the number of fibres longer than 5 microns, but still always less than 1 f/cc. The median mass measurement for each area in 1975 was generally less than 1 ng/m<sup>3</sup>, but the highest median was 25.7 ng/m<sup>3</sup>. The maximum reading at any location was 184 ng/m<sup>3</sup>. It is interesting that the highest mass occurred in Timmins, a city in the heart of Northern Ontario's mining area, where it is at least conceivable that non-asbestos mining activities might cause fibres to become airborne. Kretschmar and Kretschmar have reported various asbestos deposits in the Timmins area.<sup>74</sup> The host rock in non-asbestos mines in the area is tuffaceous, of volcanic origin, which could raise dust that might look like asbestos fibres. Only 14% of the asbestiform fibres in the Timmins data were identified as chrysotile, raising the possibility that some of the remaining fibres, while counted as asbestiform, may have been something other than asbestos.<sup>75</sup>

The Ministry of the Environment's supplementary report, containing the 1976 survey results, concluded by stating:

The fibre concentrations reported in this survey were consistently an order of magnitude smaller than comparable samples in the previous survey. This may be due to a systematic difference in the analysts' procedures, however, both programs provided internally consistent data. Since the analytical methodology was not standardized at this time, the results should be considered semi-quantitative and used for comparison purposes only. That is, those results should not be taken as a basis for air quality assessment.<sup>76</sup>

This illustrates the difficulties that have been encountered in measuring ambient asbestos levels. The concentration of fibres longer than 5 microns is indeed quite low, with median concentrations of zero or the detection limit in most locations. Once again, the concentration of fibres longer than 5 microns is a small fraction of the concentration of fibres of all lengths, indicating the typical predominance of small fibres in the samples.<sup>77</sup> Recognizing that the optical microscope cannot see thin fibres detected by the electron microscope, we could divide the count of fibres longer than 5 microns by 10, to conclude that there is very little exposure

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<sup>74</sup>Ulrich Kretschmar and Dianne Kretschmar, *Talc, Magnesite, and Asbestos Deposits in the Kirkland Lake - Timmins Area, Districts of Timiskaming and Cochrane*, Ontario Geological Survey Open File Report 5391 (Toronto: Ontario Ministry of Natural Resources, 1982).

<sup>75</sup>Ontario, Ministry of the Environment, "Asbestos as a Hazardous Contaminant, Progress Report II," Table 2, p. 26.

<sup>76</sup>Ibid., "Asbestos Air Monitoring Survey: Supplement to Report ARB-TDA-20-76," Report no. ARB-TDA-20S-78, Toronto, 1978, p. 4.

<sup>77</sup>Ibid.

greater than the optical microscope equivalent of 0.001 f/cc. However, the 1976 report discouraged the use of these figures as indicators of asbestos fibre concentrations, because of the great variation between the two sets of measurements and the undeveloped state of the measurement technology at the time. As in the 1975 survey, the mass measurements are correspondingly low, with only one median mass measurement greater than 1 ng/m<sup>3</sup> and the highest mass measurement equal to 36 ng/m<sup>3</sup>.

The most recent Ontario data have been collected in a study performed by Dr. Eric J. Chatfield of the Ontario Research Foundation for this Commission.<sup>78</sup> The results of that study are summarized in Table 11.4. This study used the direct preparation of the sample for TEM analysis rather than the indirect method used in the 1975 and 1976 Ontario studies.

The asbestos fibre concentrations found by Chatfield in the rural area near Bracebridge, Ontario, were extremely low. In analyzing 10 samples, Chatfield found only 2 small fibres. In 8 samples, no fibres were counted. Thus, the fibre concentration was reported as less than the detection limit, or 0.0005 f/cc even in the most contaminated sample. In the city of Peterborough, only 4 fibres were found in 3 samples, yielding a maximum concentration of less than 0.001 f/cc.

The other samples were taken adjacent to an expressway ramp in downtown Toronto and in two suburban locations in Mississauga and Oakville. The greatest asbestos fibre concentrations in the study were found in the expressway ramp location, but even here the maximum concentration was only 0.0042 f/cc over 5 microns in length, and the median concentration was less than 0.0033 f/cc. Thus, the maximum concentration was only 10% of the current Ontario Ministry of the Environment Ambient Air Quality Guidelines for Asbestos. The suburban fibre concentrations were still lower.

Chatfield summarized these data as follows:

The airborne chrysotile concentrations in all locations amounted to a few thousandths of a fibre/mL. No amphibole fibres were detected. The number of chrysotile fibres counted for each measurement was very low, and most of the values were close to the detection limits. Where large mass concentrations were detected, it was usually found that most of the mass was accounted for by one thick fibre.<sup>79</sup>

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<sup>78</sup>Eric J. Chatfield, *Measurement of Asbestos Fibre Concentrations in Ambient Atmospheres*, Royal Commission on Asbestos Study Series, no. 10 (Toronto: Royal Commission on Asbestos, 1983).

<sup>79</sup>*Ibid.*, p. 75.

Table 11.4  
Ontario Airborne Asbestos Concentrations\*  
1982

Location (No. of Samples)	Asbestos Fibre Concentration			Asbestos Fibre Mass		
	All Lengths			All Lengths		
	Median f/cc	Maximum f/cc	Median f/cc	Maximum f/cc	Median ng/m <sup>3</sup>	Maximum ng/m <sup>3</sup>
Toronto (12) (Expressway Ramp)	0.0034	0.0084	<0.0033	0.0042	0.025	20
Mississauga (8) (Suburb)	<0.0009	0.004	0.0007	<0.002	0.0	0.017
Oakville (13) (Suburb)	0.001	0.0063	<0.0009	0.002	0.0012	8.81
Rural (10) (near Bracebridge)	<0.0004	<0.0005	<0.0004	<0.0005	0.0	0.0079
Peterborough (3) (Small City)	0.0018	0.0019	<0.001	<0.001	0.014	0.24

**Notes:** \*All asbestos is chrysotile.

Fibres counted by TEM following direct preparation method.

**SOURCE:** The numbers in this table are derived from Dr. Chatfield's raw data. Dr. Chatfield reports confidence intervals rather than individual fibre counts. See Eric J. Chatfield, *Measurement of Asbestos Fibre Concentrations in Ambient Atmospheres*, Royal Commission on Asbestos Study Series, no. 10 (Toronto: Royal Commission on Asbestos, 1983), Tables 8, 9, 10, 11, 12, pp. 77-81.

All of the fibre counts reported in Table 11.4 were taken by electron microscope. Because the electron microscope can detect thin fibres that could not be observed under an optical microscope, the fibre concentration in Table 11.4 could be divided by 10 to approximate roughly the concentration of fibres that could be visible under an optical microscope. After dividing by 10, all concentrations of fibres longer than 5 microns would be well below the 0.001 f/cc level.

Considering all of the above data together, we conclude that asbestos fibre concentrations in the ambient air are extremely low. Counts of fibres longer than 5 microns taken by electron microscope are often less than 0.001 f/cc. If we consider the fibres that would be seen by an optical microscope, it is extremely rare in Ontario to have concentrations greater than 0.001 f/cc. The recent Ontario data suggest that fibre levels are lowest where population density is lowest, although the earlier Ontario data did not reveal this relationship. In Chapter 9 we conclude that the health risks presented to building occupants from exposure to 0.001 optically visible fibres per cubic centimetre is not significant. It follows that the fibre levels discussed in this section present a clearly insignificant health risk. We see no reason to worry about the health effects of the prevalent level of asbestos fibres in the outdoor air in Ontario.

Our conclusion that ambient asbestos fibre concentrations present no health risk is supported by at least one study of persons exposed to ambient asbestos, but not exposed occupationally. Siemiatycki studied the health of female residents of two Quebec asbestos mining towns who were not employed in the mines, but were regularly exposed to more than 1,000 ng/m<sup>3</sup> of asbestos in the air of the town, perhaps two orders of magnitude greater than the ambient concentration in Ontario. This may be considered as the equivalent of 0.03 f/cc measured optically. (See Chapter 9, Section C.) No significant excess of respiratory cancer was detected among these women.<sup>80</sup>

The 1980 *Report of the Working Group on Air Quality in the Toronto Subway System* found asbestos concentrations in the air of the subway system, measured by TEM, ranging from levels below 0.002 f/cc to 0.3 f/cc.<sup>81</sup> This study indicated that the Ministry of the Environment air quality guideline of 0.04 f/cc was exceeded in 13 out of 52 cases. This comparison

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<sup>80</sup> Jack Siemiatycki, "Health Effects on the General Population (Mortality in the General Population in Asbestos Mining Areas)," in *Proceedings of the World Symposium on Asbestos*, Montreal, Quebec: 25-27 May 1982 (Montreal, P.Q.: Canadian Asbestos Information Centre [1983]), p. 342.

<sup>81</sup> Ontario, Ministry of the Environment, Ministry of Labour, and Toronto Transit Commission, *The Report of the Working Group on Air Quality in the Toronto Subway System*, Report ARB-TDA-12-80 (Toronto: Ontario Ministry of the Environment, March 1980), p. 31.

seems to misuse the air quality guideline which was derived assuming exposure for 24 hours per day, 7 days per week. Subway patrons would rarely be exposed more than one hour per day. Operators would rarely be exposed more than 40 hours per week. In a follow-up study, undertaken after asbestos brake linings on the subway cars were replaced with non-asbestos substitutes, the Ontario Research Foundation found that none of the samples taken exceeded the Ministry of the Environment standard.<sup>82</sup> Chatfield reported some of the follow-up data in one of his studies for this Commission.<sup>83</sup>

The widespread occurrence of very low concentrations of asbestos fibres in the ambient air is confirmed by studies looking for asbestos fibres caught in human lung tissue. Uncoated asbestos fibres and asbestos bodies, which are fibres coated with iron and protein, have been discovered in the lungs of urban and rural dwellers who have not been occupationally or para-occupationally exposed to asbestos. For instance, Churg and Warnock discovered uncoated asbestos fibres and asbestos bodies in the lungs of 21 randomly selected subjects of routine autopsies who had fewer than 100 asbestos bodies per gram of lung.<sup>84</sup> They confirmed the lack of occupational exposure in 20 out of these 21 urban residents. This led them to associate this concentration of asbestos fibres and bodies with environmental exposure to asbestos. Using a variety of techniques, Churg and Warnock further identified that 80% of the fibres were chrysotile and the remainder amphiboles. The majority of both types of fibres were less than 5 microns long. This confirms that most residents of urban areas do inhale and retain some asbestos fibres as a matter of course.

### C.3 Sources of Airborne Asbestos Fibres

A number of sources may be responsible for emitting asbestos into the ambient air. Asbestos may be introduced into the air by natural mechanisms, such as wind erosion of asbestos-bearing rock and soil. In Ontario, there are natural outcroppings of asbestos, but they are in regions which are not densely populated and are not intensely farmed. Natural contamination in Ontario would constitute at most a very minor source of fibre release in rural environments and a negligible source of release in major

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<sup>82</sup>Ontario, Ministry of the Environment, Ministry of Labour, and Toronto Transit Commission, *The 1980 Follow-Up Report on Air Quality in the Toronto Subway System*, Report ARB-TDA-63-80 (Toronto: Ontario Ministry of the Environment, December 1980), Table 4.1, pp. 11-12.

<sup>83</sup>Chatfield, *Measurement of Asbestos Fibre Concentrations in Ambient Atmospheres*, Table 17, p. 94.

<sup>84</sup>Andrew M. Churg and Martha L. Warnock, "Numbers of Asbestos Bodies in Urban Patients with Lung Cancer and Gastrointestinal Cancer and in Matched Controls," *Chest* 76 (2 August 1979): 143-149.

urban areas. On the other hand, it is possible that mining activities in areas where the natural rock formations contain some asbestos may release some fibres into the air. This is suggested as the cause of elevated fibre levels found in Timmins, Ontario, in the 1976 Ministry of the Environment study discussed above.<sup>85</sup> In addition, the use of asbestos-containing mine tailings on the surface of gravel roads could cause considerable asbestos fibre release if there were a substantial asbestos content in the tailings. We are not aware that such tailings are currently used in Ontario and therefore see no need to regulate their use. In the United States, the use of such tailings for road coverings is prohibited.<sup>86</sup> If in the future the Ministry of the Environment should learn of the use of asbestos-containing tailings on gravel roads, it should conduct tests to determine the ambient fibre levels that result. If a significant problem is detected at that time, regulations prohibiting the use of asbestos-containing tailings on road surfaces should be developed.

One significant asbestos source in urban areas may be the renovation or demolition of buildings containing asbestos insulation if safe practices are not followed. This is discussed in Chapters 9 and 10.

It has been suggested that airborne asbestos fibres might result from the erosion of asphalt highway paving which contains asbestos. An asphalt mixture containing 2 to 3% chrysotile has been used as an overlay on roadways in North America. Asbestos was included because it rendered the roadway more impermeable to water and thus less likely to crack or deteriorate. Two Ontario municipalities reportedly used asbestos in the past as a binding agent with asphalt on their roads. We are not aware of any municipalities in Ontario currently using asbestos in highway coatings.<sup>87</sup>

We have seen no evidence that asbestos fibres become airborne during the wearing of roadway surfaces. Because the fibres are mixed in asphalt it seems unlikely that they could become airborne in significant quantities. We conclude in Chapter 9 that asbestos contained in liquids such as paint and roofing compounds do not present health hazards to users.

Because it is unlikely that asbestos fibres can be released from asphalt highway surfaces in significant quantities, we are not recommending that any action be taken to limit the use of asbestos-containing asphaltic highway coatings. The problem of controlling worker exposure during bag opening and mixing of asbestos with the asphalt coating is dealt with in Chapter 10. (See Recommendation 10.18.)

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<sup>85</sup> Ontario, Ministry of the Environment, "Asbestos as a Hazardous Contaminant, Progress Report II," p. 2.

<sup>86</sup> 40 CFR 61.20 et seq.

<sup>87</sup> There is one company in Ontario producing non-asbestiform tremolite for use in highway coatings.

It has been suggested that in an urban setting, wear of automotive brake linings may be a significant source of asbestos air pollution. Although there is strong evidence that asbestos fibres can be converted to non-fibrous substances during lining wear, the exact nature and levels of the emissions of wear products from brake linings is still a matter of ongoing debate. For example, Jacko and DuCharme suggested that the high temperatures experienced during vehicle braking caused 99.7% of the asbestos in the brake linings to be converted into inert and harmless particles.<sup>88</sup> Similar results were reported in work undertaken by Lynch; Hatch; Hickish and Knight; Anderson et al.; and Williams and Muhlbaier.<sup>89</sup> Williams and Muhlbaier conducted 23 analyses of wear products from disc brakes and 24 from drum brakes. They found that the average asbestos content of the wear products was 0.029%, which means that over 99.9% of the asbestos in the brake pad or shoe was transformed chemically or physically so that it was no longer an identifiable asbestos fibre.<sup>90</sup> Furthermore, they found that less than 1% of all asbestos fibres observed were longer than 5 microns. On the other hand, Alste, Watson, and Bagg concluded that the major effect of braking appears to be the separation of bundles of fibres and reduction of average length without any crystal structure alteration.<sup>91</sup> Jacko has suggested that the wear debris collected by Alste, Watson, and Bagg may have resulted from studying brake linings with poor wear characteristics.<sup>92</sup>

Rohl et al. analyzed the wear debris from brake drums of automobiles and found that in general only 3 to 6% by weight of the debris was recognizable asbestos, implying that 94 to 97% of the debris was some other material.<sup>93</sup> They further determined that such asbestos as was present in the wear debris consisted predominantly of short fibres. About 80% of the asbestos fibres in the debris were shorter than 3,750 Angstroms (0.375 microns) in length so that a very small fraction, perhaps 1%, of these fibres

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<sup>88</sup>Michael G. Jacko and Robert T. DuCharme, "Brake Emissions: Emission Measurements from Brake and Clutch Linings from Selected Mobile Sources," EPA Report 68-04-0020, NTIS PB-222-372 (Southfield, Michigan: Bendix Research Labs, March 1973).

<sup>89</sup>Jeremiah R. Lynch, "Brake Lining Decomposition Products," *Journal of the Air Pollution Control Association* 18 (1968): 824-826; D. Hatch, "Possible Alternatives to Asbestos as a Friction Material," *Annals of Occupational Hygiene* 13:1 (January 1970): 25-29; D.E. Hickish and K.L. Knight, "Exposure to Asbestos During Brake Maintenance," *Annals of Occupational Hygiene* 13:1 (January 1970): 17-21; A.E. Anderson et al., "Asbestos Emissions from Brake Dynamometer Tests," SAE Paper 730549 presented at Society of Automotive Engineers Meeting, Detroit, Michigan, 14-16 May 1973; and Ronald L. Williams and Jean L. Muhlbaier, "Asbestos Brake Emissions," *Environmental Research* 29 (1982): 70-82.

<sup>90</sup>Williams and Muhlbaier, "Asbestos Brake Emissions," p. 70.

<sup>91</sup>J. Alste, D. Watson, and J. Bagg, "Airborne Asbestos in the Vicinity of a Freeway," *Atmospheric Environment* 10:8 (1976): 583-589.

<sup>92</sup>Michael G. Jacko, "Physical and Chemical Changes of Organic Disc Pads in Service," *Wear* 46 (1978): 163.

<sup>93</sup>Arthur N. Rohl et al., "Asbestos Exposure During Brake Lining Maintenance and Repair," *Environmental Research* 12 (1976): 125.

would have been longer than 5 microns.<sup>94</sup> Thus, researchers seem to be in agreement that brake wear produces material that is 6% or less asbestos, and that less than 1% of these asbestos fibres are longer than 5 microns.

Anderson et al. calculated brake dust emission levels in the atmosphere assuming that over 99% of the asbestos was converted to harmless dust.<sup>95</sup> Utilizing an air pollution dispersion model, they estimated that urban asbestos levels from brake lining wear might be 0.07 ng/m<sup>3</sup>. Williams and Muhlbaier estimated that brake lining dust emissions might cause urban airborne asbestos concentrations of 0.063 ng/m<sup>3</sup>, less than 10% of observed urban asbestos levels reported above.<sup>96</sup> If the conversion rate were lower, so that, for example, 6% of brake wear debris consisted of asbestos fibres, then the simulated airborne asbestos levels attributable to brakes would be at least 6 times greater than the simulated levels arrived at in these studies. In this case, brake wear debris might account for half or more of the airborne asbestos fibres in urban areas. The weight of this evidence is that it is likely that automotive brakes cause only a fraction of the airborne urban asbestos detected, although it is possible that the fraction may be greater than one-half. In any event, we have found urban airborne asbestos levels to be extremely low.

There are a large number of uses of asbestos, many of which could contribute to ambient airborne asbestos levels. We conclude that ambient airborne asbestos concentrations arise from a number of sources, including automotive brakes, work on asbestos-containing buildings, fugitive emissions from asbestos manufacturing plants, and numerous other small sources. No single source is clearly dominant.

## C.4 Current Regulations

We have established above that ambient airborne asbestos fibre concentrations are generally so low that they do not present a significant health risk to the general public, even in urban areas. We have identified several probable contributors to airborne asbestos concentrations, but no one source seems to account for a large proportion of airborne asbestos, and the relative importance of various sources is as yet quite uncertain. In this situation, the purpose of establishing ambient air quality standards cannot be to protect the public from generally prevailing asbestos levels, since the risks from these levels are not significant. Furthermore, prevailing asbestos levels cannot generally be attributed to a particular source so that violations could not often lead to regulatory action. However, ambient air quality standards as well as emission standards could be used as a basis for regulat-

<sup>94</sup>Ibid., Table 2, p. 117.

<sup>95</sup>Anderson et al., "Asbestos Emissions from Brake Dynamometer Tests."

<sup>96</sup>Williams and Muhlbaier, "Asbestos Brake Emissions," p. 81.

ing the emissions from individual sources that might otherwise contribute substantially to airborne concentrations. There follows a review of existing regulations of airborne asbestos levels. These regulations focus upon controlling emissions from individual sources.

#### (a) The United States

In March 1971, the Environmental Protection Agency of the United States named asbestos as a hazardous air pollutant. In April 1973, the National Emission Standard for Asbestos was passed under section 112 of the *Clean Air Act, 1970*, providing that there must be no "visible emissions" to the outside air from asbestos mills, various manufacturing and fabricating establishments using asbestos, asbestos spraying operations, and friable asbestos-containing demolition and renovation sites.<sup>97</sup> In lieu of meeting the "no visible emissions" standard, specific air-cleaning procedures may be followed. The use of asbestos tailings for the surfacing of roadways is expressly prohibited.

The transportation of commercial asbestos is governed by the Asbestos Regulation of the U.S. Department of Transportation.<sup>98</sup> Commercial asbestos must be transported in rigid, leak-tight packaging, non-rigid packaging in enclosed vehicles, or dust- and silt-proof, non-rigid packages which are placed in fibreboard or wooden boxes or which are palletized and unitized (unless transported by private carrier by highway). The container must be marked as containing asbestos.

#### (b) The United Kingdom

There is little specific statutory control over asbestos in the ambient air in the United Kingdom. Several laws provide the authority to regulate pollution, including asbestos release, but this authority has not been exercised by specific asbestos regulations. The U.K. Advisory Committee on Asbestos recommended more specific control over the emission of asbestos dust from the workplace and recommended that imported raw asbestos be packed in totally enclosed metal-clad containers and that the transportation of asbestos products liable to produce dust be performed so as to prevent the escape of any dust.<sup>99</sup> These recommendations have not yet been acted on. However, it seems that draft regulations dealing with emissions from the workplace and with the transportation of new asbestos, among other substances, are now under consideration in the United Kingdom.<sup>100</sup>

<sup>97</sup> 40 CFR 61.20 et seq.

<sup>98</sup> 49 CFR 173.1090, 44 FR 47937, 16 August 1979.

<sup>99</sup> U.K., Advisory Committee on Asbestos, *Asbestos — Volume 1: Final Report of the Advisory Committee*, Recommendations 32, 35, and 36, pp. 89, 91.

<sup>100</sup> Telephone communication between Mr. Stanley King and Royal Commission on Asbestos Staff, 29 June 1983.

**(c) Canada — Federal Provisions**

In Canada, the federal *Clean Air Act* authorizes monitoring and research with respect to air pollutants.<sup>101</sup> In addition, the Asbestos Mining and Milling National Emission Standards Regulations, passed under the *Clean Air Act*, establish an emission standard applicable to asbestos mills or mines of 2 f/cc (over 5 microns and with a length to width ratio of 3 to 1 or more).<sup>102</sup> Mine and mill operators are required to keep records of emission measurements and to provide them to administrative authorities when requested.<sup>103</sup> The regulations specifically provide that they do not affect more stringent provincial emission standards.<sup>104</sup> The more general Ambient Air Quality Objectives Order No. 1, passed under the same Act, does not set an objective for asbestos, but does provide that the presence of suspended particulate matter be considered "acceptable" only at levels of 60 to 70 milligrams per cubic metre (mg/m<sup>3</sup>) (annual) or 0 to 120 mg/m<sup>3</sup> (24 hours) and "desirable" at a level of 0 to 60 mg/m<sup>3</sup> (annual).<sup>105</sup> These concentrations, being in milligrams, are a million times greater than asbestos concentrations, in nanograms, normally found in outdoor air and are therefore irrelevant for asbestos control. Regulations are currently being developed to govern establishments manufacturing asbestos-containing products.<sup>106</sup>

Finally, the Canada Dangerous Substances Regulations,<sup>107</sup> promulgated under the *Canada Labour Code*,<sup>108</sup> provide that every employer must ensure that any "dangerous substance" that may be carried into the air be confined as closely as is "reasonably practicable" to its source.<sup>109</sup>

**(d) Other Provinces**

The provinces are entitled to regulate the intra-provincial emission of pollutants, as related to their jurisdiction over property and civil rights, and matters of a local and private nature.<sup>110</sup> All provinces have enacted legisla-

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<sup>101</sup>S.C. 1970-71-72, c. 47.

<sup>102</sup>*Clean Air Act*, Asbestos Mining and Milling National Emission Standards Regulations, CRC, Vol. IV, c. 405, s. 4(1), p. 2875.

<sup>103</sup>*Ibid.*, s. 6(1).

<sup>104</sup>*Ibid.*, s. 3.

<sup>105</sup>*Clean Air Act*, Ambient Air Quality Objectives Order 1, CRC, Vol. IV, c. 403, p. 2869.

<sup>106</sup>Glasbeek, *A Survey of Asbestos Policies in Canada with Particular Emphasis on Ontario*, p. 42. Confirmed in telephone communication between Mr. R. Capowski, Environment Canada and Royal Commission on Asbestos Staff, 17 May 1983.

<sup>107</sup>*Canada Labour Code*, Canada Dangerous Substances Regulations, CRC, Vol. X, c. 997, p. 7749.

<sup>108</sup>R.S.C. 1970, c. L-1.

<sup>109</sup>Canada Dangerous Substances Regulations, s. 9.

<sup>110</sup>*Constitution Act, 1867* (formerly named the *British North America Act, 1867*), ss. 92(13) and 92(16).

tion governing public health, most of which provides for control of "nuisances" by local health authorities. "Nuisance" is typically defined to include any activities that may be harmful to the health of the general public and consequently can be extended to the presence of asbestos.

Most provinces have enacted legislation governing the emission of pollutants or contaminants in the air. With the exceptions of Quebec, British Columbia, and Ontario, provinces have not promulgated specific emission standards for asbestos, although standards governing particulates and asphalt plants may be indirectly applicable.

Quebec's Regulation Respecting the Quality of the Environment restricts emissions from establishments processing asbestos to 2 f/cc (over 5 microns in length and with a length to width ratio of at least 3 to 1).<sup>111</sup> When loading asbestos, the same standard, or in the alternative a standard of "no visible emissions" from a distance of 2 metres, is prescribed.

British Columbia's Pollution Control Objectives for the Mining, Smelting and Related Industries provide that asbestos emissions should be restricted to 2 f/cc (greater than 5 microns in length and with a length to width ratio of at least 3 to 1). These objectives are enforced as conditions on permits assigned to emitters. As well, British Columbia has adopted an ambient air guideline for asbestos of 0.04 f/cc; this guideline does not have the force of law.<sup>112</sup>

#### (e) Ontario

The *Public Health Act* of Ontario, like similar legislation enacted in other provinces, allows local public health authorities to regulate "nuisances" which, by definition, include "[a]ny condition . . . that is or may become injurious or dangerous to health . . ."<sup>113</sup>

The *Environmental Protection Act* of Ontario prohibits emissions of "contaminants" in excess of prescribed levels<sup>114</sup> and emissions which may impair the quality of the environment, harm any person, or adversely affect the health of any person.<sup>115</sup> The General—Air Pollution Regulations promulgated under that Act establish prescribed emissions levels.<sup>116</sup> While they

<sup>111</sup>O.C. 3845-80 (1981) 113 *Gazette Officielle* II 87.

<sup>112</sup>Telephone communication between Mr. W.H. Weldon, Technical Services Division, Waste Management Branch, British Columbia Ministry of the Environment and Royal Commission on Asbestos Staff, 12 July 1983.

<sup>113</sup>R.S.O. 1980, c. 409, s. 115.

<sup>114</sup>R.S.O. 1980, c. 141, s. 13.

<sup>115</sup>*Ibid.*, s. 13(1).

<sup>116</sup>R.R.O. 1980, Reg. 308.

do not specifically apply to asbestos, the general visible emissions standard included therein may be applicable.

The Ministry of the Environment has developed a 30-minute average emission standard for asbestos of 5 micrograms per cubic metre at the closest point of impingement. In addition, the Ministry has adopted a 24-hour ambient air quality objective of 0.04 f/cc over 5 microns in length, discussed earlier in this section.<sup>117</sup>

## C.5 Discussion and Recommendations

There are two elements to standard-setting for ambient air quality: ambient air quality objectives can be established and emission standards set. Air quality objectives state the acceptable level for a particular pollutant in the ambient air. This level must be established after considering evidence on the health and nuisance problems associated with particular levels of a contaminant in the ambient air. Air quality objectives are not directly enforceable unless it is possible to show that a particular emitter is causing the ambient air objective to be exceeded. The primary usefulness of an ambient air quality objective is that it may identify air quality problems.

Emission standards are directly enforceable in that they relate to emissions from individual sources. In setting an emission standard, it is necessary to consider how the relevant air quality objective can be met. With a common contaminant, like asbestos, the emission standard must be set low enough so that the various sources of the contaminant collectively do not cause the air quality objective to be exceeded. A number of factors must be taken into account, including the physics and chemistry of air transport of the substance. A large element of judgement is unavoidable.

We cannot fully endorse or reject Ontario's existing ambient air quality objective of 0.04 f/cc longer than 5 microns because of the continuing lack of agreement in the scientific community on how environmental measurements should be taken. Today, different analysts use different methods of evaluating environmental air samples, with substantially different results. Chatfield has shown that the indirect preparation method, even when performed in the same laboratory by the same technicians, yields both more fibres and more mass than does the direct preparation method.<sup>118</sup>

<sup>117</sup>Ontario, Ministry of the Environment, Air Resources Branch, "List of Tentative Standards, Guidelines and Provisional Guidelines for Air Contaminants," January 1982.

<sup>118</sup>Chatfield, *Measurement of Asbestos Fibre Concentrations in Ambient Atmospheres*, pp. 83-94.

With the development of an internationally accepted measurement method, better data on the size distribution of asbestos fibres in the ambient air should emerge. Such data would permit an improved understanding of the relationship between TEM (or other) data and the optical microscope data which have been gathered in the work setting and on which the health evidence in relation to the inhalation of asbestos is based. It would then be sensible to reassess Ontario's ambient air quality objective for asbestos.

We do, however, believe that the 0.04 f/cc ambient air quality guideline now in force in Ontario provides a reasonable interim standard. The 0.04 f/cc guideline, combined with the ability of the TEM to detect more thin fibres than the optical microscope, provides more than adequate protection to the public during this interim period. We note that West Germany is contemplating an ambient air quality guideline for asbestos of 1 fibre per litre, or 0.001 f/cc, longer than 5 microns measured by TEM.<sup>119</sup> Our conclusion on the health risks associated with asbestos in the ambient air indicates that the risk reduction, if any, afforded by such a guideline over one that was, say, one order of magnitude greater, is trivial or insignificant.

We believe that the current Ontario ambient air quality criterion for asbestos should remain in force, pending the development of an internationally accepted measurement method. We accordingly recommend that:

*11.5 The Ministry of the Environment, in co-operation with the Ministry of Labour, should financially support the development of internationally accepted methods for ambient air quality measurement and adopt such measurement methods when they have been adopted by such international bodies as the International Organization for Standardization.*

Once a method for measuring ambient asbestos concentrations has been adopted internationally, and is approved by the Ontario Ministry of the Environment, the Ministry should review the 0.04 f/cc asbestos guideline. In selecting the appropriate level, we believe it would be appropriate for the Ministry of the Environment to consider our conclusion that the health risks presented to the public by protracted exposure to the optical microscope equivalent of 0.001 f/cc longer than 5 microns would not pose a significant health risk to the general public. This assessment of risk from exposure to 0.001 f/cc longer than 5 microns is based on extensive, rather than short-term, exposure. Where the typical period of exposure is brief, considerably higher levels might safely be allowed.

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<sup>119</sup>Ibid., Table 16, p. 92.

The emission standard for asbestos now in place in Ontario is 5 micrograms per cubic metre, at the closest point of impingement. This standard is not related to concentrations of fibres longer than 5 microns, as is the current Ontario ambient air quality guideline. Consistent with our conclusion that long, thin asbestos fibres pose the greatest health risk, we believe that the technique for measuring asbestos-containing emissions should focus on fibres longer than 5 microns. As discussed in Chapters 7 and 9, the relationship between mass measurements of fibres of all sizes and concentrations of long, thin fibres is variable. Mass measurements are generally determined by counting fibres by TEM and determining mass based on this fibre count. The mass determination is unnecessary for the purpose of detecting fibres longer than 5 microns. Long fibres can be counted more accurately if the operator is not distracted by counting the far more numerous short fibres.

As well, fibre counting usually proceeds by examining portions of a microscope grid and counting the fibres found therein until some specified number of fibres has been reached. Accordingly, if short fibres are included in the count, counting will be abandoned when relatively few long fibres have been found; when short fibres are not included, a larger portion of the grid is examined and a greater number of long fibres found.

We conclude that the 5 microgram per cubic metre emission standard should be replaced with a standard specified in terms of fibres per cubic centimetre longer than 5 microns. This emission standard should at present be set so as to be consistent with the current Ontario ambient air quality guideline. We accordingly recommend that:

*11.6 The Ministry of the Environment should revise the emission standard for asbestos to specify concentrations of fibres longer than 5 microns. This standard should be consistent with the existing ambient air quality criterion for asbestos.*

The emission standard for asbestos should be reassessed when a new ambient air quality criterion for asbestos is set. As stated above, this should follow the establishment of an internationally accepted measurement method.

## **D. Waste Disposal**

### **D.1 Current Practices and Exposures**

The increase in asbestos waste generated by the removal of asbestos-containing insulation from buildings has heightened the problems of asbestos waste disposal in Ontario. Until 1979, the waste management policy of the Ministry of the Environment was based on the premise that

asbestos waste was derived from fixed industrial sources, for example, friction products manufacturing. However, with the implementation of programmes to remove asbestos-containing insulation from schools and other buildings, the waste disposal problem has been highlighted and has changed in character. The disposal of asbestos waste from asbestos-containing insulation removal projects, as well as waste from fixed industrial sources, must be subject to a regulatory framework. This is to protect waste disposal workers themselves.

When asbestos is deposited in a landfill site, degradation of the asbestos will depend on the nature of the site, including soil conditions. The report of the U.K. Advisory Committee on Asbestos explained: "If conditions are very acidic, which may occur from other chemical waste disposal, then chrysotile asbestos may well be degraded, although amphibole asbestos varieties will be virtually unaffected by changes in the acidity or alkalinity of disposal sites. Composite wastes such as asbestos cement may be subject to chemical changes in the soil which would remove the bonding agents, leaving the asbestos fibre unaffected. Similarly, resinated asbestos materials would be subject to bacterial and chemical attack which would free the fibrous component which would remain virtually undegraded."<sup>120</sup> However, even if the asbestos does not degrade, the potential for fibres to migrate through soil is minimal,<sup>121</sup> unless the sites are dug up or are situated on "... fissured, fractured or jointed strata leading to aquifers and where water-filled sites are in hydraulic continuity with surface and groundwater resources . . . ."<sup>122</sup> Accordingly, asbestos fibres deposited in appropriate landfill sites and properly overlaid are unlikely to contaminate air or water resources.

A study undertaken by Her Majesty's Factory Inspector (HMFI) in the United Kingdom between 1976 and 1977 investigated levels of asbestos in the ambient air around waste disposal sites. Atmospheric dust sampling was carried out at 79 different waste disposal sites. Of the 236 samples taken, 25% were from the breathing zone of the workers, 65% from the background, and 10% from outside the site perimeter. Only 2 non-crocidolite samples exceeded the occupational hygiene standard then in force for non-crocidolite asbestos fibres of 2 f/cc, with readings of 2.3 and 2.4 f/cc. The vast majority of samples collected ranged from 0.01 to 0.2 f/cc. Two samples which contained crocidolite exceeded the 0.2 f/cc stan-

<sup>120</sup>U.K., Advisory Committee on Asbestos, *Asbestos — Volume 1: Final Report of the Advisory Committee*, paragraph 46, p. 37.

<sup>121</sup>Wallace H. Fuller, *Movement of Selected Metals, Asbestos and Cyanide in Soil: Applications to Waste Disposal Problems*, EPA-600/2-77-020 (Cincinnati, Ohio: U.S. Environmental Protection Agency, 1977), p. 4.

<sup>122</sup>U.K., Department of the Environment, *Waste Management Paper No. 18, Asbestos Wastes: A Technical Memorandum on Arisings and Disposal Including a Code of Practice* (London: Her Majesty's Stationery Office, 1979), p. 11.

dard then in force for crocidolite, with readings of 0.6 and 8.6 f/cc. The reading of 8.6 f/cc may be explained by the fact that split bags were observed spilling their contents on the site where the sample was taken. This suggests that negligent work practices when disposing of asbestos waste lead to elevated airborne asbestos fibre levels at disposal sites. None of the samples taken by the HMFI beyond the site boundaries yielded figures in excess of the hygiene standard.<sup>123</sup>

The above data indicate the need for appropriate work practices for the disposal of asbestos waste. Such work practices will protect both disposal workers and members of the public dwelling near disposal sites.

Since asbestos is not highly degradable, workers involved in future developments of asbestos-containing landfill sites may be at a risk from exposure to airborne asbestos fibres. Accordingly, it is important that records be kept regarding the locations of asbestos waste, so that those workers may be protected.

Operators of waste disposal sites in Ontario are not required to accept asbestos waste. We have been informed that in a number of areas in the province, municipal waste site operators have refused to accept waste materials generated from asbestos-containing insulation removal projects. Removal contractors have accordingly had to rely on private disposal sites. However, some private site operators are also reluctant to permit asbestos to be dumped at their sites. As a result, removal contractors are forced to stockpile waste material near the sites of removal operations. The Commission has learned of occasions when asbestos scraps were transported to farmers' fields and dumped there for minimal fees. In other cases, asbestos waste has been indiscriminately placed in open pits.<sup>124</sup> Accordingly, it is necessary that a system be devised that ensures the availability of adequate and safe asbestos dumping grounds.

It appears that the Ministry of the Environment has not been sufficiently diligent in monitoring asbestos waste disposal, in stark contrast to the extensive precautions undertaken to protect workers during removal of asbestos from buildings. Dissatisfaction with the Ministry of the Environment's monitoring of waste disposal is widespread in the asbestos removal industry. In discussions with our staff, contractors have urged that if downstream treatment of asbestos waste is not rigorously handled by the Ministry of the Environment, then following a rigorous regime to prevent asbestos exposure during asbestos removal may be pointless.

<sup>123</sup> U.K., Advisory Committee on Asbestos, *Asbestos — Volume 1: Final Report of the Advisory Committee*, paragraphs G5-G6, p. 43.

<sup>124</sup> The staff of the Royal Commission on Asbestos has had discussions with removal contractors, government safety inspectors, and waste disposal site operators on these matters.

The Ministry of the Environment has largely left to the Ministry of Labour the monitoring of known asbestos waste sources to ensure conscientious preparation and handling of asbestos waste materials. However, the Construction Health and Safety Branch of the Ministry of Labour has told the staff of this Commission that little attention is paid by its field personnel to the waste transfer and disposal stages of asbestos removal operations. Moreover, because the Ministry of Labour does not require notification of contracts valued at less than \$50,000, many waste-generating operations are completely unregulated.<sup>125</sup>

The monitoring of dump sites by the Ministry of the Environment has been criticized. For example, in Ottawa, *The Citizen* published a series of reports on asbestos waste disposal at the Nepean dump in May 1981. In that case, for three months, "... drums [of asbestos], instead of being buried in a special area of the dump, went to the normal landfill site where they were run over by compacting machines or tossed down a 10-metre-deep gully, causing them to burst open and spilling their contents."<sup>126</sup> Until *The Citizen* warned the site operator, he was unaware of special handling procedures for asbestos. Furthermore, although the Ministry of the Environment officer was aware that asbestos was being deposited in the Nepean dump, he was not acquainted with the specific techniques that should be employed by dumps when they dispose of asbestos waste. We have been told that similar incidents have occurred at dump sites elsewhere in Ontario.<sup>127</sup>

## D.2 Current Regulations: The United States, The United Kingdom, and Ontario

### (a) The United States

Procedures for the disposal of asbestos waste generated from manufacturing, demolition, renovation, and spraying operations in the United States are outlined in the Environmental Protection Agency's National Emission Standard for Asbestos.<sup>128</sup> Disposal operations must meet the "no visible emissions" standard or, in the alternative, compliance with the regulation may be achieved by waste being wetted, sealed in a leak-tight container, and labelled;<sup>129</sup> or by processing asbestos waste into non-friable

<sup>125</sup> Construction Projects Regulation, R.R.O. 1980, Reg. 691, s. 4(1)(a), under the *Occupational Health and Safety Act*, R.S.O. 1980, c. 321.

<sup>126</sup> See *The Citizen* (Ottawa), 5, 6, 7 May 1981.

<sup>127</sup> The staff of the Royal Commission on Asbestos has had discussions with asbestos removal contractors and dump site operators.

<sup>128</sup> 40 CFR 61.20 et seq.; 40 CFR 61.22(j).

<sup>129</sup> 40 CFR 61.22(j)(3)(i).

forms.<sup>130</sup> In the case of waste from asbestos mills, the last alternative is not acceptable. The owner or operator of the waste-producing source is responsible for compliance with the waste disposal regulation.

Active waste disposal sites must exhibit no visible emissions or, in the alternative, asbestos waste must be covered daily with non-asbestos-containing material.<sup>131</sup> Warning signs must be displayed on the waste disposal site property and at all entrances.

Inactive waste disposal sites that once received asbestos must meet the "no visible emission" standard or cover the asbestos waste with non-asbestos materials.<sup>132</sup> The warning sign provisions applicable to active sites also govern inactive sites.

In all cases, the owner or operator of the existing source must provide to the EPA information concerning the type of disposal site used, the name and location of the site, and the name of the site operator.<sup>133</sup>

### (b) The United Kingdom

Under the *Control of Pollution Act, 1974*, local authorities are given the power to establish licensing schemes for the control of waste,<sup>134</sup> and power to designate and regulate "special waste," meaning those wastes which may be dangerous or difficult to dispose of.<sup>135</sup> The Control of Pollution (Special) Waste Regulation of 1980 passed under this statute includes asbestos in the definition of "special waste."<sup>136</sup> Consignment notes are required to be used by producers, carriers, and disposers of waste. Labelling and disposal requirements are outlined as well.

### (c) Ontario

Waste disposal in Ontario is currently governed by Part V of the *Environmental Protection Act* through the General—Waste Management Regulation promulgated under that Act.<sup>137</sup>

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<sup>130</sup>40 CFR 61.22(j)(3)(ii).

<sup>131</sup>Fifteen centimeters of non-asbestos-containing material or a resinous or petroleum-based dust suppression agent [40 CFR 61.25(c)(1) and (2)].

<sup>132</sup>Fifteen centimeters of non-asbestos-containing material and a vegetation cover or 60 centimeters of compacted non-asbestos-containing material or a resinous or petroleum-based dust suppression agent [40 CFR 61.22(k)(5)].

<sup>133</sup>40 CFR 61.24(c).

<sup>134</sup>22–23 Eliz. II, c. 40, ss. 1 and 2.

<sup>135</sup>*Ibid.*, s. 17.

<sup>136</sup>S.I. 1980/1709, s. 2(1) and Schedule I, Part I.

<sup>137</sup>See R.S.O. 1980, c. 141 and R.R.O. 1980, Reg. 309 thereunder.

Part V of the *Environmental Protection Act* requires that all "waste disposal sites" and "waste management systems" be certified.<sup>138</sup> The definition of "waste management systems" includes collection, transportation, and handling of waste; hence certified approval is required of haulers of waste. Use of uncertified facilities is prohibited.<sup>139</sup>

In March 1983, the Ministry of the Environment filed a Regulation amending the General—Waste Management Regulation with regard to asbestos waste.<sup>140</sup> This 1983 Regulation defines "asbestos waste" as solid or liquid waste that contains asbestos in more than a trivial amount or proportion.<sup>141</sup> Procedures for handling asbestos waste are prescribed by the 1983 Regulation.

Under the 1983 Regulation, no person may cause or permit asbestos waste to leave the location at which it was generated, except for the purpose of transporting it to a waste disposal site, the operator of which has agreed to accept it.<sup>142</sup> The asbestos waste must be placed in rigid, impermeable, sealed containers. If the container is a cardboard box, the waste must be sealed in a 6 mil polyethylene bag placed within the box.<sup>143</sup> If the asbestos waste is transported in bulk, it must be transported by means of a waste management system operating under a certificate of approval specifically authorizing the transportation of asbestos waste in bulk.<sup>144</sup> A specific caution against asbestos hazards is required to be placed on containers and vehicles.<sup>145</sup> Drivers transporting asbestos waste must be trained in asbestos waste management and must transport the waste as directly as is practicable to the waste disposal site.<sup>146</sup> Vehicles carrying asbestos waste in cardboard boxes must be enclosed. In all other cases, vehicles that are not enclosed must be covered with a suitable tarpaulin or net.<sup>147</sup>

Once deposited at a disposal site, asbestos waste must be covered forthwith with at least 125 centimetres of garbage or cover material.<sup>148</sup> Every person handling asbestos waste or its containers, supervising the unloading of asbestos waste in bulk, or cleaning asbestos waste residues from containers, vehicles, or equipment must wear protective clothing and personal respiratory equipment.<sup>149</sup> There are provisions for proper handling

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<sup>138</sup> R.S.O. 1980, c. 141, s. 27.

<sup>139</sup> R.S.O. 1980, c. 141, ss. 39 and 40.

<sup>140</sup> O. Reg. 175/83.

<sup>141</sup> O. Reg. 175/83, s. 1(1).

<sup>142</sup> *Ibid.*, s. 14(1).

<sup>143</sup> *Ibid.*, ss. 14(1) and 14(2).

<sup>144</sup> *Ibid.*, s. 14(1).

<sup>145</sup> *Ibid.*, s. 14(5).

<sup>146</sup> *Ibid.*, s. 14(6).

<sup>147</sup> *Ibid.*

<sup>148</sup> *Ibid.*, s. 14(11).

<sup>149</sup> *Ibid.*, s. 14(12).

of protective clothing.<sup>150</sup> Finally, all persons involved in the transportation, handling, or management of asbestos waste must take all necessary precautions to prevent asbestos waste from becoming airborne.<sup>151</sup>

### D.3 Recommendations

We endorse the steps recently taken by the Ministry of the Environment in regulating the handling of asbestos waste. We expect that proper enforcement of its 1983 Regulation will greatly improve asbestos waste handling in this province. Dissatisfaction with asbestos waste handling in Ontario hitherto expressed by members of the asbestos removal industry should accordingly be alleviated.

The 1983 Regulation on asbestos waste appears to apply to all sources of asbestos waste. We believe that it is not realistic to expect that this Regulation would be effectively enforced in dealing with sources of small amounts of asbestos waste, such as those generated by brake lining repair work. We accordingly recommend that:

*11.7 The Ministry of the Environment should amend the 1983 General—Waste Management Regulation made under the Environmental Protection Act so as to provide that the sections regulating asbestos waste apply only to asbestos waste generated by asbestos removal operations and by asbestos product manufacturing.*

It is necessary that the Ministry of the Environment be notified prior to the transportation of asbestos waste, so that the regulation of asbestos waste management can be properly enforced. We accordingly recommend that:

*11.8 The Ministry of the Environment should amend the 1983 General—Waste Management Regulation made under the Environmental Protection Act so as to require that the Ministry be notified, prior to the transporting of asbestos waste, of the quantity of the waste, the nature and destination of the waste, the type of packing involved, and any other pertinent details.*

We note above that there is concern over the availability of disposal sites for asbestos waste in Ontario, because disposal site operators sometimes refuse to accept such waste. Moreover, we have noted that when asbestos is deposited in disposal sites without records being kept as to its precise location, workers on future disposal site developments are placed at

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<sup>150</sup> Ibid., ss. 14(13) and 14(14).

<sup>151</sup> Ibid., s. 14(15).

risk. While these sites cannot be redeveloped for 25 years after their being used for waste disposal without the special permission of the Minister of the Environment,<sup>152</sup> available evidence suggests that asbestos waste may not degrade over such a period. Accordingly, we conclude that asbestos should be deposited either in designated, recorded areas of existing disposal sites or, if necessary, in special asbestos disposal sites, and that the Ministry of the Environment should take steps to ensure that there are adequate facilities for the disposal of asbestos waste. We therefore recommend that:

*11.9 The Ministry of the Environment should amend the 1983 General—Waste Management Regulation made under the Environmental Protection Act so as to require that precise records be kept as to the location of deposited asbestos waste. The content and storage of these records should be specified by the Ministry.*

We further recommend that:

*11.10 The Ministry of the Environment should determine which disposal site operators are prepared to accept asbestos waste. If this determination indicates that there are not adequate disposal sites for receiving asbestos waste in the province, the Ministry of the Environment should either establish special asbestos disposal sites or consider requiring certain disposal site operators to accept asbestos waste.*

We are also concerned about disposal sites where asbestos was dumped in the past. For example, Johns-Manville has reported to the Commission that there are 1.6 million tons of landfill material present at its Scarborough plant area, of which up to 5% is asbestos. Johns-Manville has plans to redevelop this area.<sup>153</sup>

Workers involved in the eventual redevelopment of disposal sites which contain significant quantities of asbestos should be protected. It is advisable that policy be developed as to the restrictions on redevelopment that should apply to such sites. We accordingly recommend that:

*11.11 The Ministry of the Environment should develop policies regarding the redevelopment of waste sites known to contain substantial quantities of asbestos.*

Finally, there is the problem of asbestos having been disposed of in unidentified sites in the past. Where it is reasonably practicable, it would be desirable to identify the location of substantial quantities of asbestos waste

<sup>152</sup>R.S.O. 1980, c. 141, s. 45.

<sup>153</sup>Letter from Johns-Manville Canada Inc. to the Royal Commission on Asbestos, 31 August 1981.

so that the policies developed under Recommendation 11.11 can be applied to them. We therefore recommend that:

***11.12 The Ministry of the Environment should, where reasonably practicable, endeavour to identify sites in which substantial quantities of asbestos have been deposited.***



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